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Algorithm Organization

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COMPUTER IDENTIFICATION OF P WAVES IN ELECTROCARDIOGRAMS

THESIS

AFIT/GE/EE/77-16 Charles A. Flick
Capt. USAF

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Capt USAF

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Preface

This thesis develops a computer algorithm that will locate and identify the P wave in an electrocardiogram (ECG). This program does not assume that the P wave is located a certain distance from the R wave or other landmarks in the ECG. This will allow the program to locate disassociated P waves.

I would like to thank those who have contributed their time and guidance in this research. I give special thanks to my thesis advisor, Dr. Matthew Kabrisky, who proposed this study. Edwin L. Stanley, M.D., Staff of Cox Heart Institute, and M. Edward Womble, Ph.D., Clinical Science Division, School of Aerospace Medicine, gave valuable guidance.

I also wish to thank my wife Carol, for the support she has always given me.

Charles A. Flick

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Abstract

Algorithms to locate and identify the P wave in single lead electrocardiograms (ECG's) are developed and evaluated on eighteen 12 second electrocardiogram recordings. The program does not assume that the P wave has any specific time relationship to the occurrence of the QRS complex. The program searches the entire ECG to locate the P wave in any part of the ECG. The program divides the ECG into sections and classifies the sections as P waves or some other wave. The first test selects the sections that have a frequency domain pattern that is similar to a training set P wave. The sections that pass this test are checked for a periodic relationship with past selected sections. If a section was selected at a time assumed to be one P wave period before the present one, the present one will be classified as a P wave. Of the 209 P waves in the ECG records, 123 or 58.85% were located correctly. There were 83 false classifications of sections which were not P waves.

COMPUTER IDENTIFICATION OF P WAVES IN ELECTROCARDIOGRAMS

I. Introduction

The purpose of this thesis is to develop a computer program that can identify the P wave in an electrocardiogram (ECG) without restricting the region of the search. The program will not require operator intervention to initiate ECG monitoring.

Background

Coronary Care Units (CCU's) have been set up in most hospitals to care for people who have suffered heart attacks. Up to a few years ago, nurses visual monitored the ECG's of every patient in the CCU. Now computers are beginning to become useful in supplementing continuous human monitoring of the ECG's, primarily to warn the nursing staff if the patient's condition is deteriorating (Refs 7,10).

The ECG is a graphical representation of the electrical activity of the heart. A cardiologist can learn a great deal about the present condition of the heart from it. The ECG has three important deflections, as shown in Figure 1. The P wave is caused by the contraction of the atrium or upper chamber of the heart. The QRS complex and the T wave are caused by the ventricles or lower chamber of the

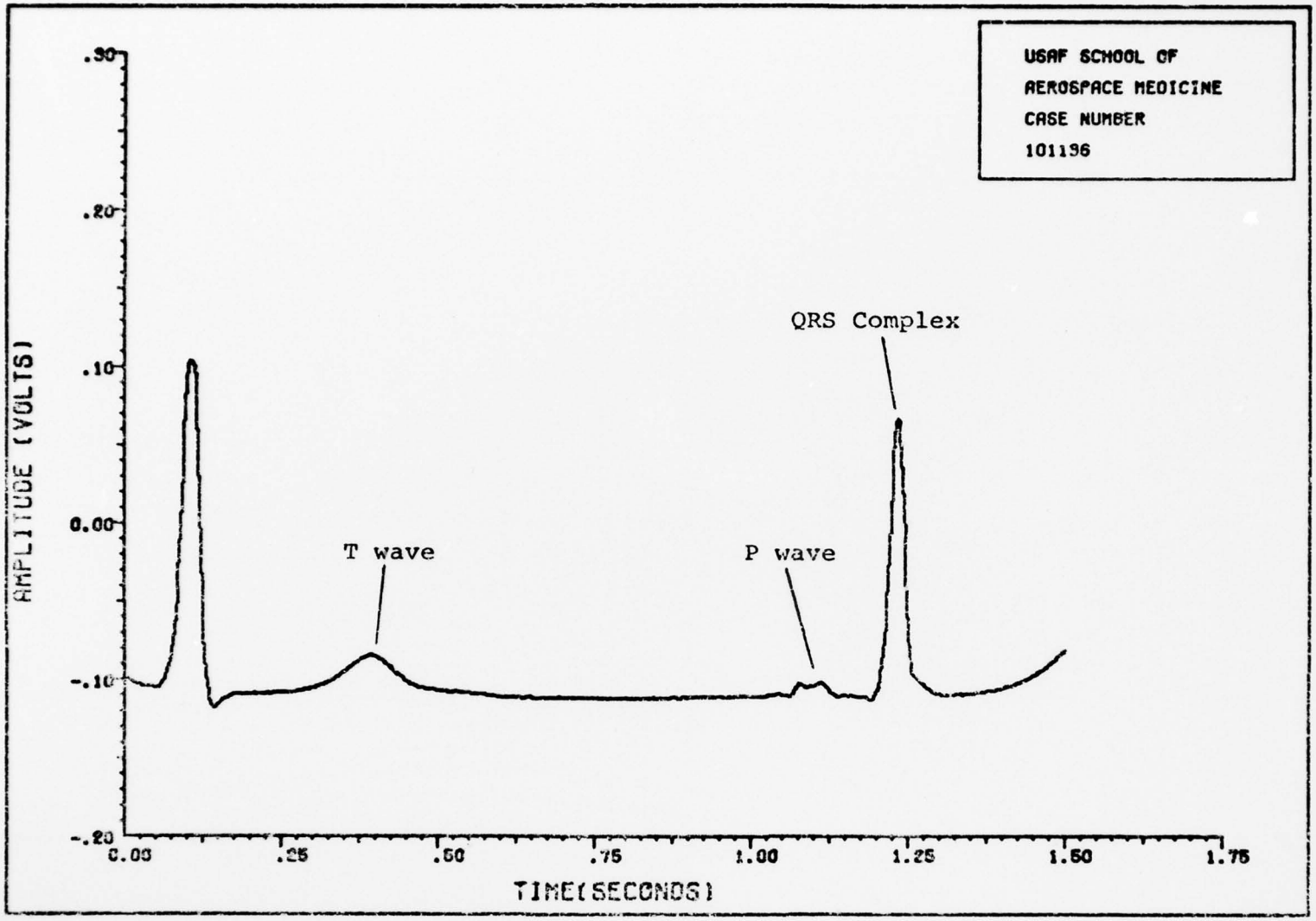

Figure 1. ECG Record 7

heart. In the ECG of a normal heart, the QRS complex occurs a fixed time after the P wave. A signal that is sent from the atrium to the ventricles causes the ventricles to contract at the proper time. This signal may be delayed or completely blocked in a heart that has suffered a heart attack. If the signal is delayed, the ECG will have a longer distance between the P wave and the QRS complex. If the signal is completely blocked, the ECG will have a variable distance from the P wave to the QRS complex. The ECG will resemble two unsynchronized signals, usually with slightly different repetition rates. This type of ECG is said to have a disassociated P wave. Contemporary computer algorithms used to monitor the patients in a CCU accurately warn of most dangerous cardiac problems; but none of them can locate a disassociated P wave.

Previous computer programs designed to locate the P wave have assumed that it would be located just before the QRS complex. This restricts the search for the P wave to only this area of the ECG. The programs are simple and reasonably accurate for most cases but may fail completely if the ECG has a disassociated P wave. Lt. Charles Pairett at the Air Force Institute of Technology developed such a program which achieved a 96% location rate for P waves that were not disassociated (Ref 14). He did not test it with any disassociated P wave ECG's; however, he did state that this would cause the location of erroneous waves. The program developed for this thesis does not make the

assumption that the P wave is located between the T wave and the QRS complex and it searches all of the ECG.

Limitations

The program is designed to be only a subroutine of a complete ECG monitoring system. It is assumed that the monitoring program will supply the QRS to QRS interval to the P wave locating subroutine. The P wave locating program only classifies a section of the ECG as a P wave and does not specify the exact location of the peak or the beginning or end of the P wave.

Electrocardiogram Records

The ECG data used to develop and test the programs were furnished by the USAF School of Aerospace Medicine. They contain the three lead electrocardiogram of 18 patients of the School of Aerospace Medicine and were received as digitized records on a computer tape. The three analog components (X,Y,Z) of the ECG were sampled at a 512 samples/second rate and digitized as 16 bit integers which are interleaved (X_1, Y_1, Z_1, X_2, Y_2, Z_2, . . .) on the tape. To prepare the data for use in this thesis, the X component data were separated and placed on a computer file. The X component was selected as the lead to be analyzed because its P waves had greater amplitude than the other leads. Appendix A contains samples from each of the 18 records. The computer programs used to process the data are listed in Appendix B.

Algorithm Organization

The programs developed for this thesis use the Tektronix 1410 Computer Display Terminal operating in a time sharing mode on the CDC 6600 computer. The programs are written in Fortran IV Extended and use subroutines from the Tektronix Plot-10 graphics system (Ref 15).

The first program was used to interactively select sections of the ECG to examine and to save these sections as a training set for the feature selection process. The program plots the ECG on the screen of the terminal and allows the operator to select a part of the display to analyze. The operator can view a frequency domain representation of the selected section. The program was also used to obtain frequency domain data from P wave, T wave and quiescent sections of the ECG.

The second program locates P waves using frequency domain and rhythm analysis. It plots the ECG on the terminal and indicates what sections are classified as P waves. Appendix B contains the source code of both programs.

II. Initialization Algorithm

The initializing algorithm is used to collect and analyze data. The product of the analysis is a set of constants used in the classification process of the program to locate P waves. The data are collected using the prototype location algorithm and analyzed using the stepwise discriminant analysis.

Prototype Locating Algorithm

The program developed for this thesis allows the operator to locate examples or prototypes of each of the classes of waveforms in the ECG and to examine a plot of the frequency domain components. The program can also save these components so they may be used for feature selection. The program is interactive and prompts the operator at each step of the data collection process. The flowchart for this program is shown in Figure 2.

Select Mode. At the start of the program, the operator selects how the program will be used. The program is set to process the sections in one of three modes.

1. Plot the complex components of the Fast Fourier Transform (FFT).
2. Plot the discrete power spectrum.
3. Output the FFT and the discrete power spectrum.

The first two modes are used by the operator to learn about the frequency domain characteristics of the data.

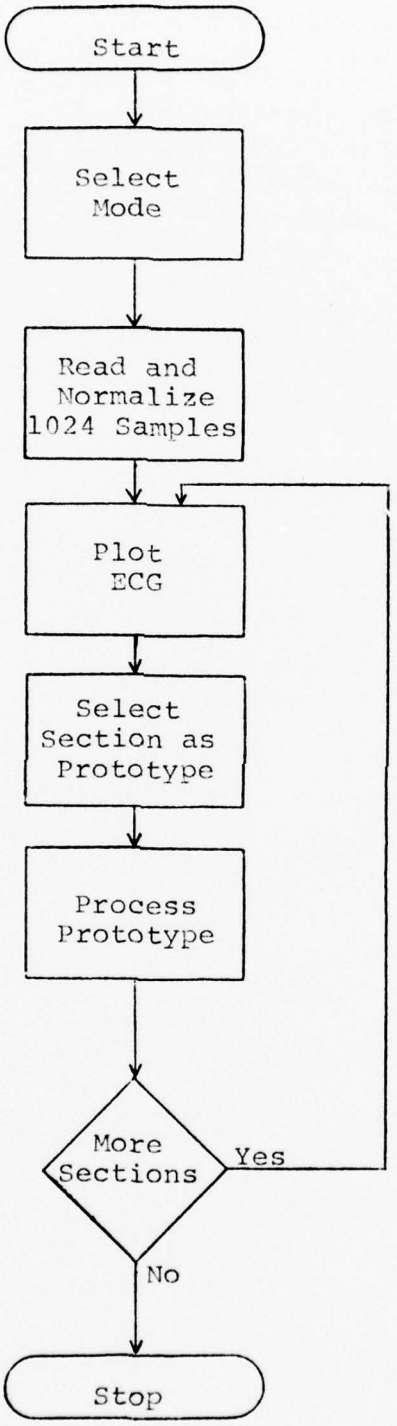

Figure 2. Prototype Locating Flowchart

The number of sample points contained in the prototype is selected at the start of the program and must be the same as used in the program to locate P waves. A prototype size of 32 samples was used for the thesis because this is the approximate size of a typical P wave. The prototype may be set as large as 64 samples.

Read and Normalize 1024 Samples. The program reads 1024 samples from a computer file and places them in an array. The arithmetic mean of the samples is calculated and subtracted from each sample. The standard deviation of the samples is found and is divided into each sample. This produces an array with a mean of zero and a standard deviation of one. It also removes some of the most common nonphysiological variations from the ECG. The ECG amplifier gain and the electrode placement and resistance can cause the peak to peak amplitude of the ECG to vary. These variations can be minimized by dividing each sample by the standard deviation of the samples. Vertical shifts in the ECG can be caused by movements of the patient. This can be minimized by normalizing the mean of the data. The program to locate P waves uses the same normalizing process.

Plot ECG. The ECG is plotted on the terminal screen with a scale that indicates sample location. Figure 3 shows the terminal display of the prototype locating program.

Select Section as Prototype. After the ECG is plotted on the terminal screen, a section of the ECG can be selected

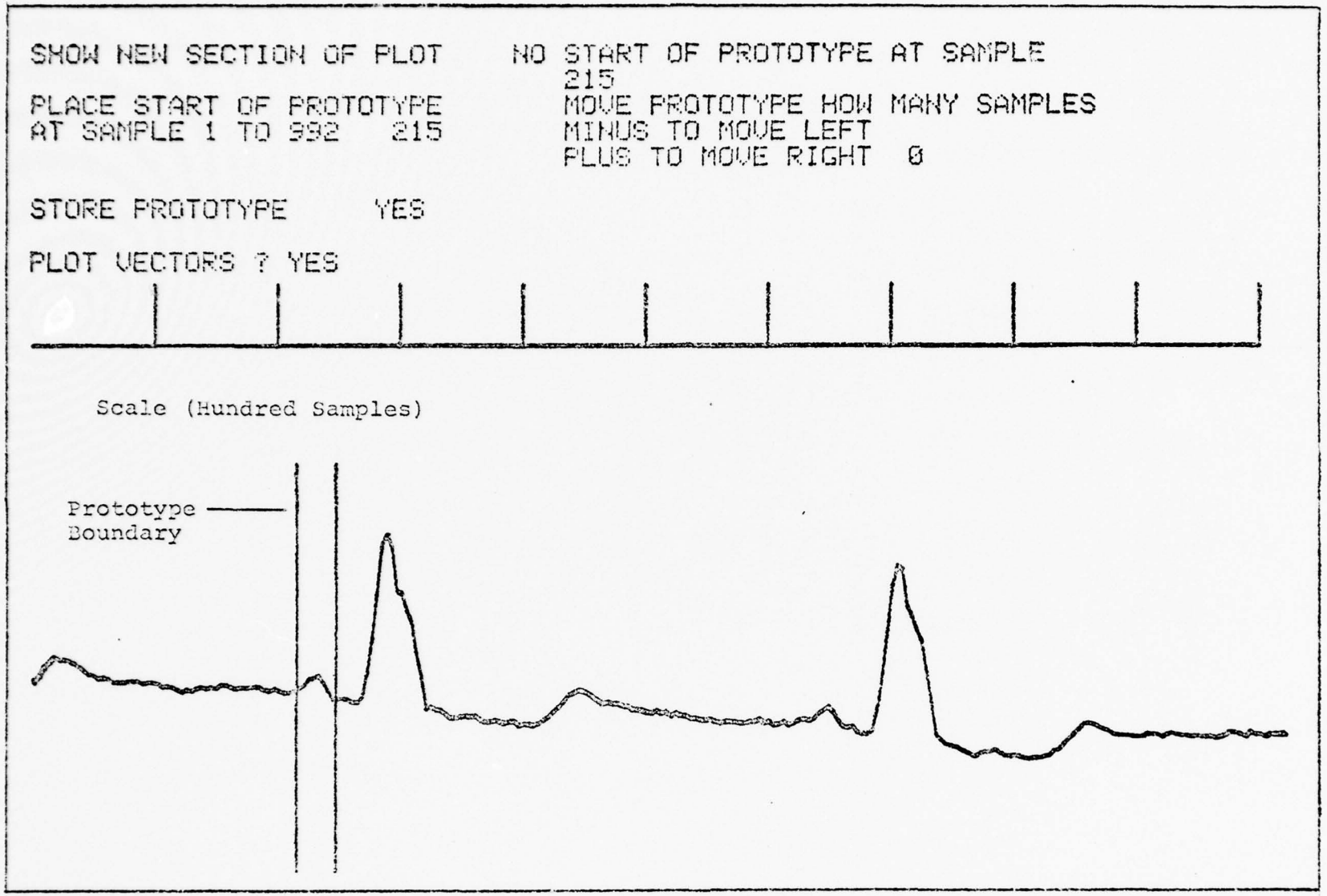

Figure 3. Prototype Locating Display

by the operator to examine or save. To select a section, the starting points sample location is entered on the keyboard of the terminal. The program then draws two vertical lines that delimit the prototype. If the placement of the boundaries is not correct, the location can be moved. When it is placed correctly, the selected section will be processed according to the mode selected at the start of the program.

Process the Prototype. The samples of the selected section are placed into the first 32 real elements of a 64 element complex array and then the rest of the elements are set to zero. A 64 point FFT is performed on this array. The FFT subroutine operates only on arrays which have dimensions that are powers of two (Ref 13). A 64 sample FFT was used to make the FFT components frequency increments smaller and also to allow the prototype size to be greater than 32 samples. Only the eight low frequency components of the FFT were used in the program because they contain most of the energy of the ECG.

If the program is set to display the frequency domain data, the value of the component is plotted along the abscissa and the components are the ordinate. If the FFT components are plotted, the order of the components is one to eight of the real and then two to nine of the imaginary as shown in Figure 4. If the discrete power spectrum is plotted, the order is from one to eight. The discrete power spectrum is calculated from the components of the FFT.

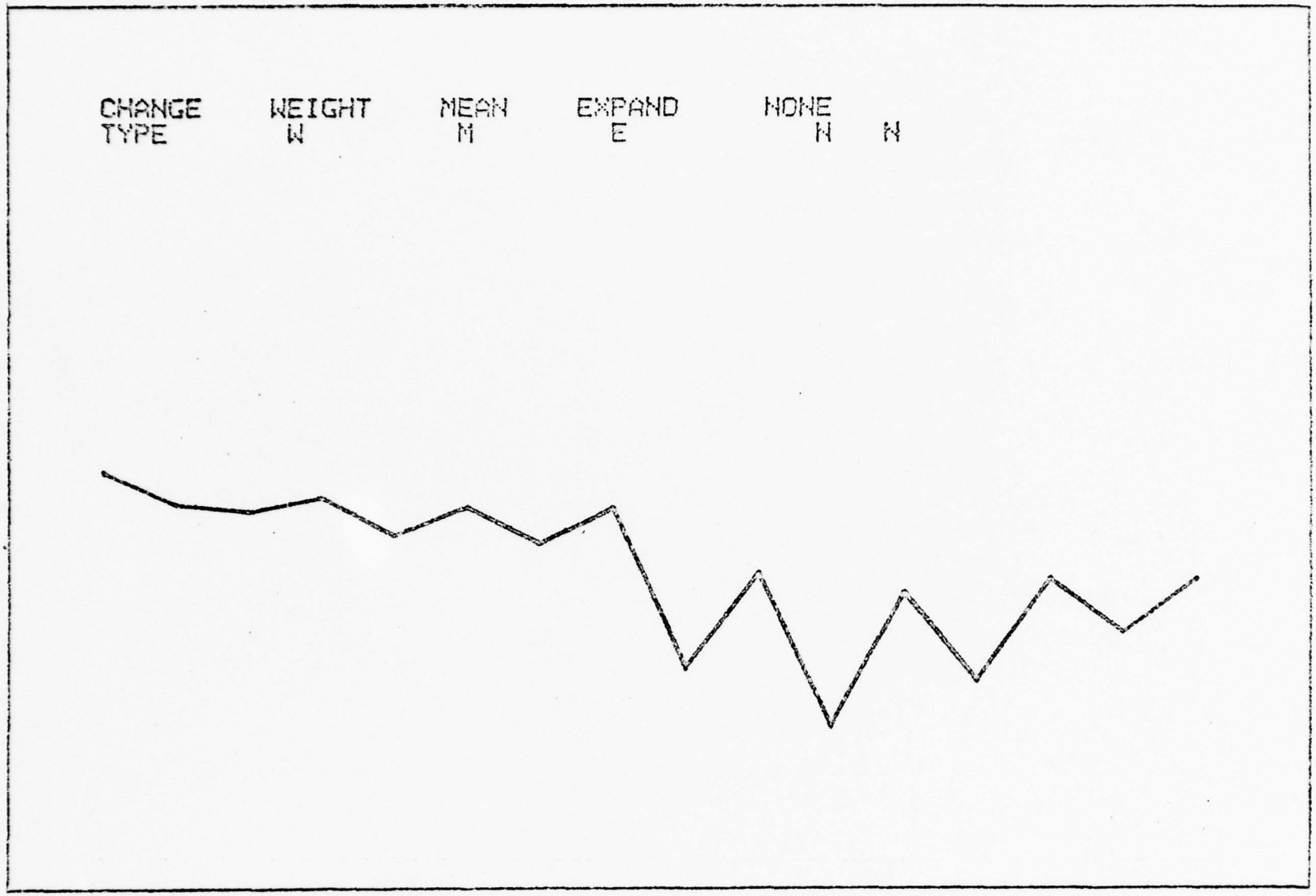

Figure 4. Prototype FFT Components

Each component is equal to the square root of the sum of the square of the real and imaginary terms of the FFT. There are interactive commands that allow the expansion of the amplitude of the whole plot or each components amplitude can be changed.

If the program is set to collect prototypes to be used in feature selection, the FFT components and the discrete power spectrum are placed on a computer file. The components are selected and calculated as described above. Each selected section of the ECG could be represented as a data vector in 23 space using these components.

Stepwise Discriminant Analysis

The stepwise discriminant analysis is used to select the eight components of the frequency domain data which best separates the training set P waves from the other waveforms in the training set. The training set was formed from four ECG's using the program described earlier. The components selected by the stepwise discriminant analysis were used by the program to locate P waves for all the ECG's. This allowed the program to locate P waves in a new ECG without performing feature selection.

The training set was divided into three groups: P wave, baseline, and T wave. The P wave class contained only P waves. Any waveform that was not a P wave and had less energy than a P wave was placed in the baseline class. The T wave class contained T waves and also QRS waveforms and premature ventricular contractions (PVC's).

The stepwise discriminant analysis program used for this thesis is called BMD07M and was developed by UCLA (Ref 5). The program performs a multiple discriminant analysis in a stepwise manner. At each step the program adds or deletes a component to improve the separation between groups. When the most important components have been selected, the canonical variables are formed using these components. The canonical variables map the frequency domain data from 23 space into the decision space.

For each of the canonical variables, the program calculates a weight for each of the selected components. A canonical variable is equal to the summation of each component multiplied by its weight plus a constant to position the variable. A three class problem requires a two dimensional decision space; so two canonical variables are created to define the X and Y axes. The group mean is calculated by evaluating the canonical variables using the mean value of each of the components of the group.

The variables can be used to map new data into one of the three classes. The frequency domain components of a section of an ECG will represent a point in this decision space. If the three groups had equal a priori probabilities and using a minimum probability of error decision criterion, the wave should be classified into the group whose mean is closest to the waveform in the decision space.

The program provides statistical information about the training set and outputs the constants for the canonical

variables and values of the three group means. It also plots the classification space with the group means and the training set points as shown in Figure 5. The constants of the two canonical variables and the three group means are inputs to the program to locate P waves.

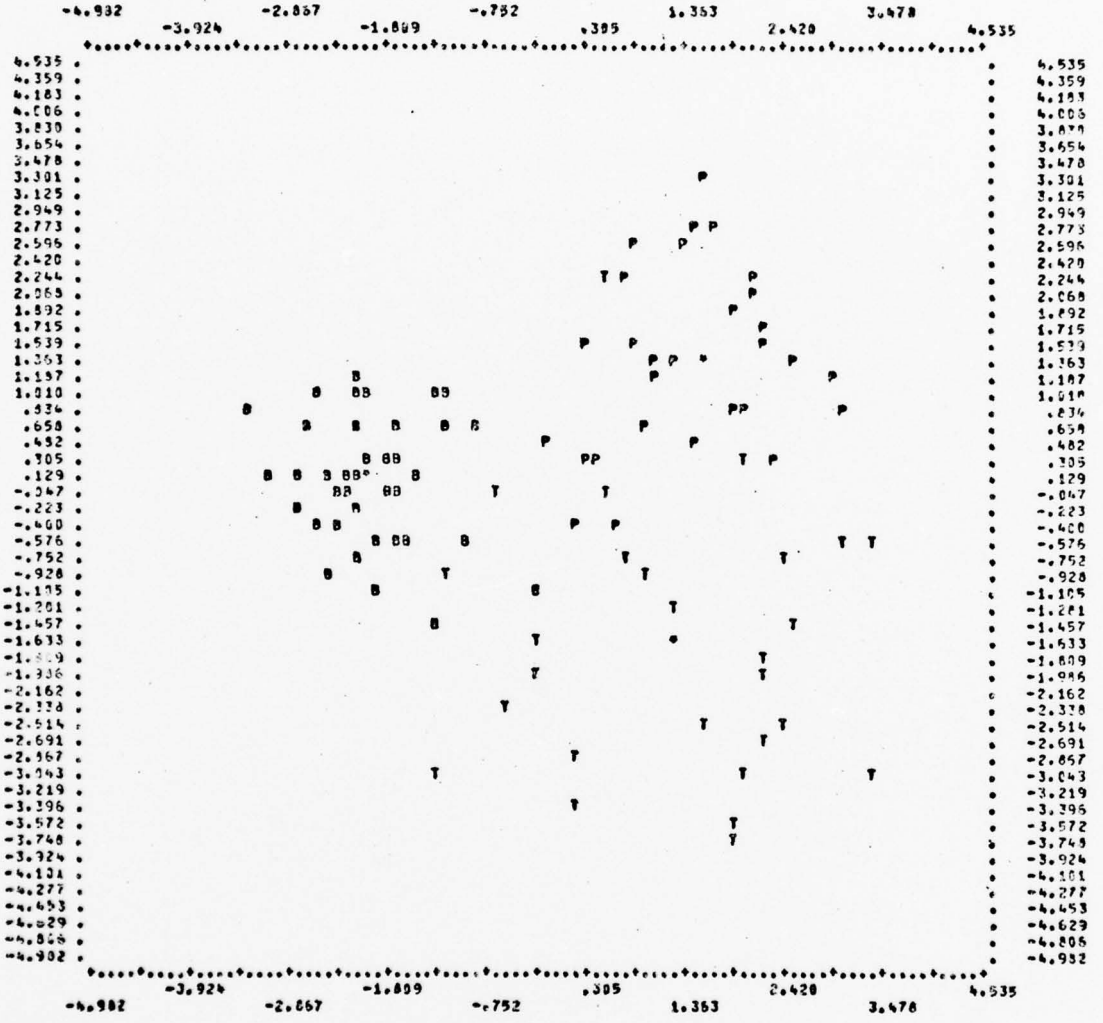

Figure 5. BMD07's Plot of the Decision Space

III. Location Algorithm

The program to identify P waves plots the ECG on the terminal screen, divides it into sections and classifies each section. Two tests are used to select the sections to be classified as P waves. The first test selects the sections that have a frequency domain pattern similar to the training set P waves. The sections that pass this test will be called candidates and they are tested for a periodic relationship. If a candidate was selected at a time assumed to be one P wave period before the present candidate, the one under test will be classified as a P wave. The flowchart for this program is shown in Figure 6.

Initialize Program

The values of the constants of the two canonical variables and the group means for the P wave, T wave and baseline classes are read from a computer file. The value of the constants in the canonical variables for the components that were not selected in the feature selection is zero. The constants for the selected components are equal to the values assigned by the BMD07M program.

Read and Normalize 1024 Samples

An array is filled with 1024 samples from a computer file containing the ECG data. The array is normalized by subtracting from each element the mean value of the array. The standard deviation of the array is found and each element is divided by it. This removes some of the

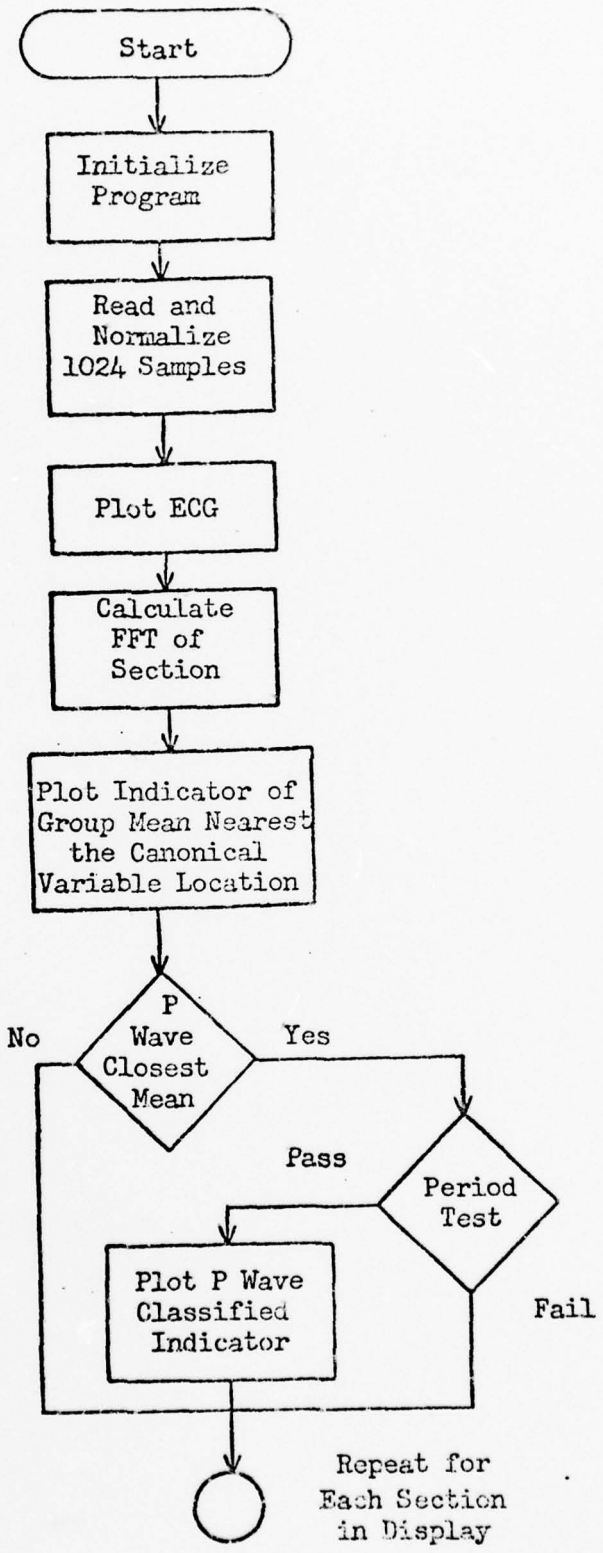

Figure 6. P Wave Locating Flowchart

variation in the signal that is caused by nonphysiological sources. This is the same normalization used in the program to collect data for the feature selection.

Plot Electrocardiogram

The 1024 samples of the normalized array are plotted on the terminal screen as shown in Figure 7. Except for the first and last 128 samples, the display is divided into overlaping sections which are 32 samples wide and overlap 16 samples. The exclusion of the first and last 128 samples is necessary because the ECG displays overlap.

Calculate the FFT of Section

The 32 samples of the section are placed into a 64 element complex array and the FFT is performed on it. As in the first program, the low frequency FFT components are selected and the discrete power spectrum is created from the magnitude of the FFT components.

Plot Indicator of Group Mean Nearest the Canonical Variable Location

The two canonical variables are calculated by summing the product of each component found in the last step and its constant selected by the initialization algorithm. The two variables represent a point in the two dimensional decision space. The euclidean distance from this point to each of the group means found in the initialization algorithm is calculated.

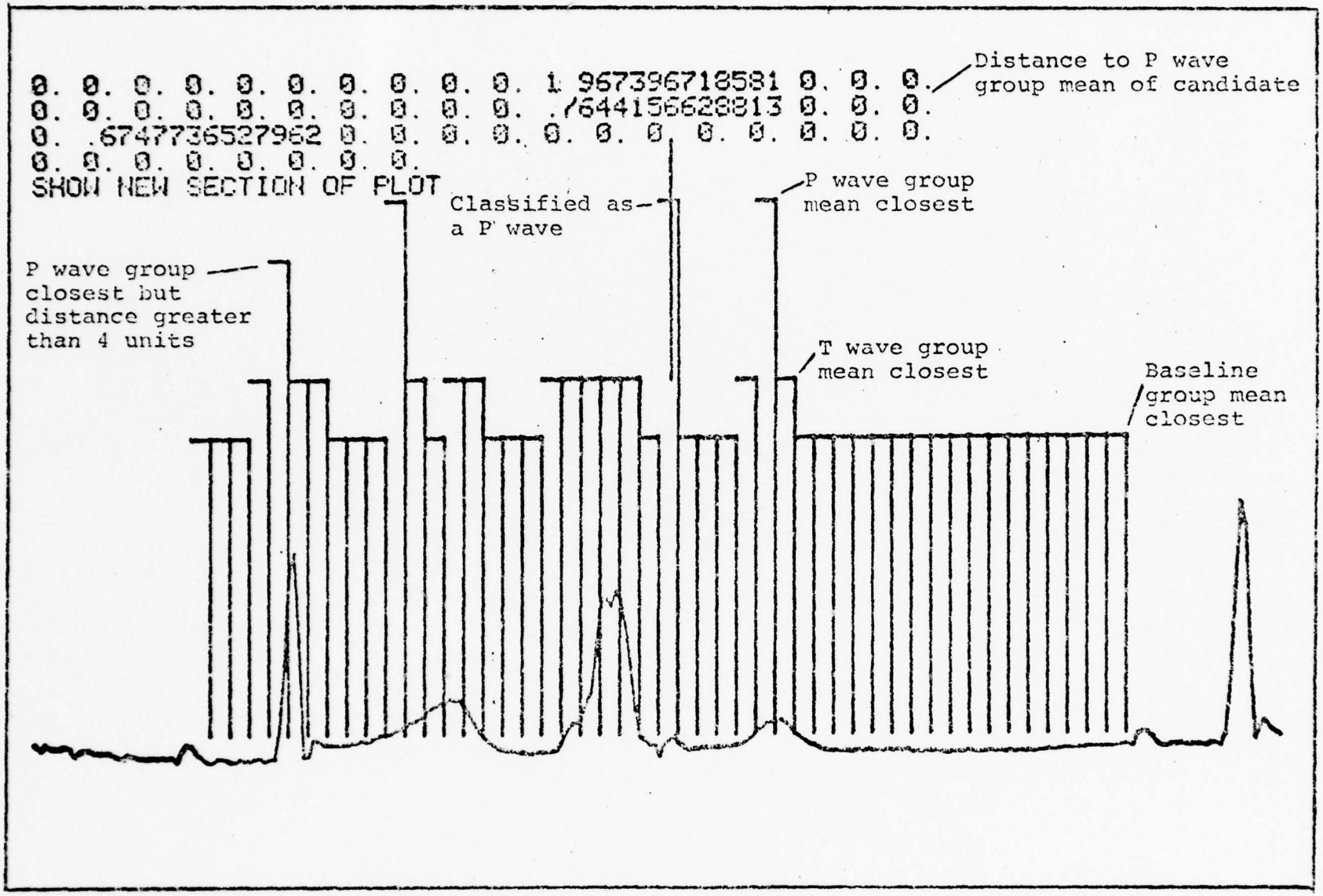

Figure 7. P Wave Location Display

A vertical line is drawn on the terminal screen to indicate the starting location of the section and a horizontal line is drawn to indicate which group mean was nearest the location of the canonical variables. The baseline indicator is the lowest, the T wave is above the baseline, and the P wave is the highest. Some waveforms that are not P waves will have decision space locations that are closer to the P wave group mean but at a distance greater than any of the P waves in the training set. All the P waves in the training set mapped into a cluster less than three units from the group mean. If the P wave group mean is the closest but the distance is more than four units, it will not be selected as a candidate P wave and will be indicated by a height that is between that of the P wave and the T wave. These indicators are shown in Figure 7.

Period Test

If the section was selected as a candidate P wave, a second test will check for the periodic occurrence of the candidates. The P wave, which is caused by the contraction of the atrium, is normally periodic. The atrium's contractions are rhythmic because it is controlled by the sinoatrial node in the heart. This will occur even if there is damage to the heart which causes a disassociated P wave in the ECG. The period test will classify the section as a P wave if a candidate was selected at a time assumed to be one period before the present one.

The time assumed to be the P wave period is found by examining a histogram of candidate occurrences in which each entry is equal to the number of previous candidates that were separated by that number of display sections. The histogram locations that represent possible P wave repetition rates are searched for the maximum value. The R wave period, which is easier to measure than the P wave period, is used to bound the region of search. The period of the P wave could be from 1.1 to .5 times the period of the R wave. The period test is implemented by using two arrays.

1. Array PICKED contains the history of which of the last 50 display sections were selected as candidates.
2. Array HIST contains the histogram of candidate occurrence for distances from one to 50 display sections.

The array PICKED contains a flag, the value one, to indicate when a section was selected as a candidate. Otherwise it is blank with the value zero. The subscript of the element indicates the location of the display section that it represents. The first element represents the present section and the second element represents the previous section. When the program goes to the next section, it shifts the array to the right. The flags are now in elements with subscripts that are one greater. The last element, which represents the section 51 units away, will be lost.

The array HIST is used to find the distance between candidates that occurs most often and this is assumed to be the P wave PERIOD. Each time that a candidate is selected, the array PICKED is added to the array HIST element by element. The array HIST is then searched over the range of possible P wave periods. The R wave period, which is used to define the range of search, is entered on the terminal after viewing the first display of the ECG. In an operational monitoring program, this information would be obtained from the main program. When the largest value is found in the search region of array HIST, the subscript is used as the center of the test window for the array PICKED. If a flag is found in three sample wide test window, the section is classified as a P wave. Figure 8 shows the arrays HIST and PICKED as histograms with the search region and the test window shown. To indicate that a section has been classified as a P wave, a vertical line is drawn on the screen through the center of the section as shown in Figure 7. After all the sections in the display have been analyzed and the results indicated on the terminal, each section's distance from the P wave group mean is printed. The sections that were not selected as candidates are represented by zeros.

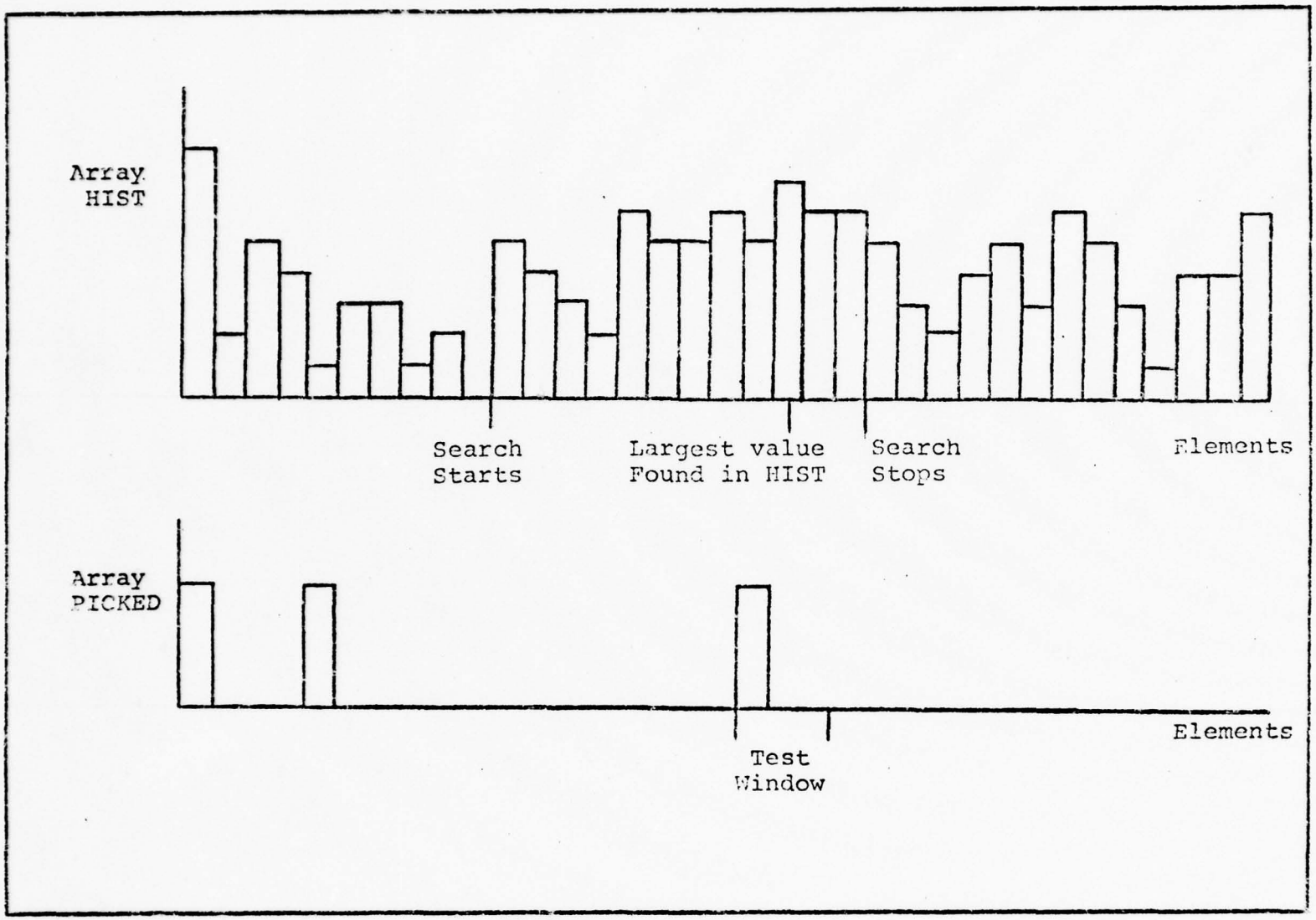

Figure 8. Histogram of Candidate Occurrence

IV. Results

The results will be discussed in two sections. First the initialization algorithm results describe the selection of the training set, the analysis procedure and the product of the analysis. Then the results of the location algorithm describes the performance of the P wave locating program using the 18 ECG records.

Initialization Algorithm Results

A training set was selected and then analyzed to find the important features to be used to select candidates in the program to locate P waves. The training set prototypes were all obtained from the ECG records one to four. Several prototypes were produced from each P wave with it positioned differently in each prototype. Its position in the prototype window was shifted eight samples from the last prototype. This continues as long as the prototype contains at least 80% of the energy of the wave. This provides two to three prototypes from each P wave and a total of 113 P wave prototypes. The peak of each of the T waves was selected as part of the training set. The T wave group, which also included four PVC's and five QRS complexes, contained a total of 69 prototypes. The baseline class contained 64 randomly selected prototypes from sections of the ECG which contain little energy.

The BMD07M discriminant analysis program was used to analyze the training set and produce the two canonical

variables used to select the candidates in the P wave location program. The BMD07M program plots the location of the group means and all the prototypes in the training set in the decision space. The program also produces a table that shows how the prototypes of each of the groups will be classified using the canonical variable as a decision rule. For example, it states how many of the P wave prototypes will be classified as members of the P wave, T wave and baseline groups. Both of these outputs were used to evaluate the separation of the groups and the reliability of the decision rule. The separation of the T wave and baseline groups was not considered important. The goal in feature selection was to maximize the number of P wave prototypes classified as P waves and to minimize the number of other group prototypes that are classified as P waves.

The membership of the T wave and baseline groups was manipulated to improve the separation of the P wave group from the other groups. Initially, the three groups were analyzed by the program and the decision space plot showed that the P wave and baseline groups formed tighter clusters around their means than the T wave group. Twenty-five of the outer T wave prototypes were separated into a fourth class, called OUT, which was not used in any of the feature selection calculations but was plotted in the decision space to ensure that they continued to be located away from the P wave mean. The prototypes placed in the group OUT

included all the QRS complexes. The first decision space plot showed that some of the T wave prototypes were closer to the baseline group mean than the T waves; so they were transferred to that group.

The initial BMD07M program analysis classified 80% of the P wave prototypes as P waves and 15% of the other two classes prototypes as P waves. After rearranging the prototypes, the results improved to 86% correct P wave classification and only 10% of the other three groups prototypes were classified as P waves. The finial decision space plot is shown in Figure 9. The symbols P, B, T and O represent prototypes of the groups P wave, baseline, T wave and OUT, respectively. The * indicates the location of a group mean. The $ indicates that two or more prototypes are located at that point. The eight components selected as the most important are the FFT real components two, three, four and five. Also the power spectrum components two, three, seven and eight were selected. None of the imaginary components of the FFT were selected. The values of the constants selected for the canonical variables are given in Table I. The three group means are listed in Table II.

Location Algorithm Results

The P wave locating program was evaluated using the 18 ECG records. The performance of the candidate selection and the total algorithm is discussed separately. The data

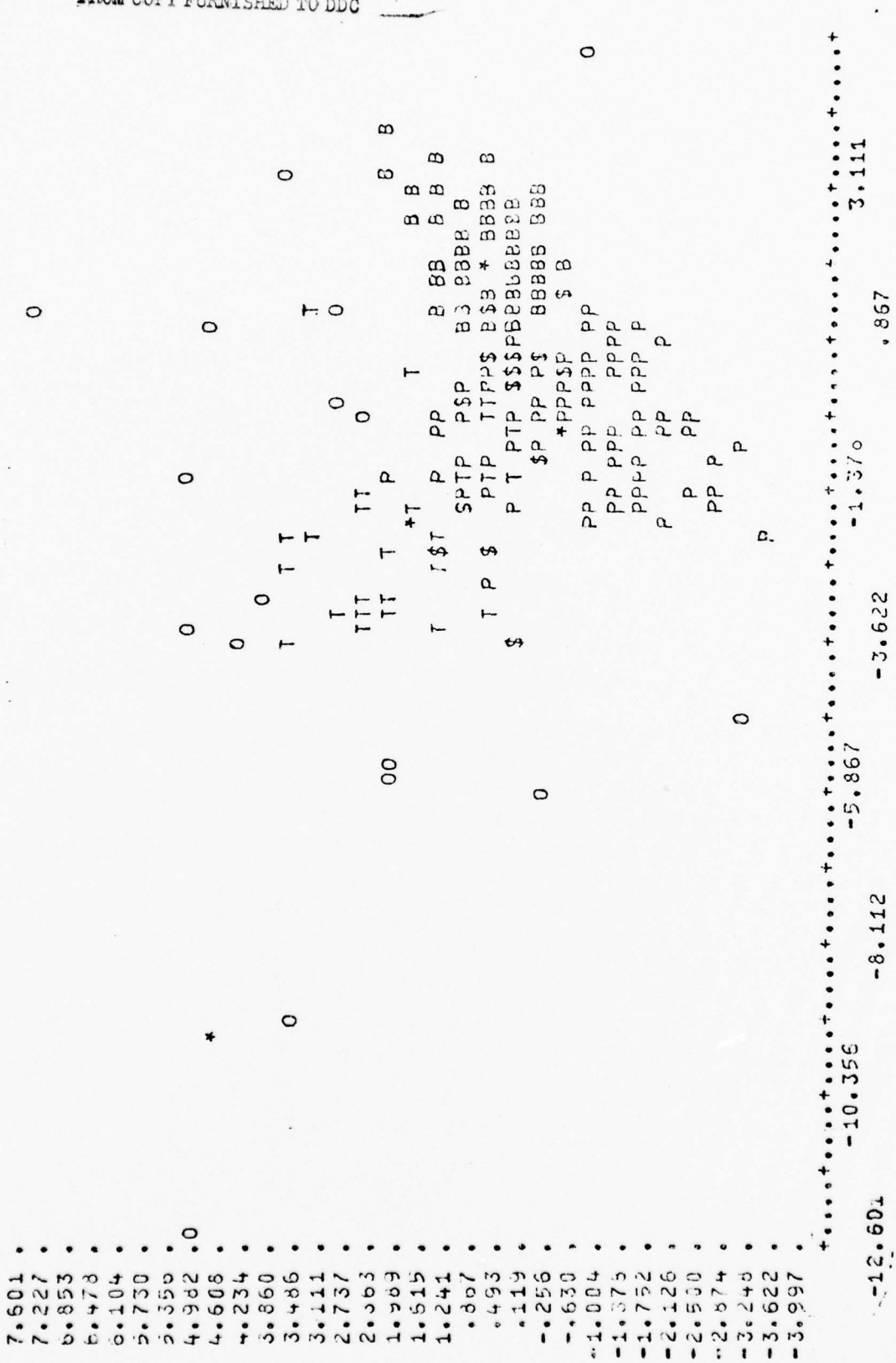

Figure 9. Finial Decision Space Plot

Table I

Constants of the Canonical Variables

Components	Variable X	Variable Y
Real FFT		
2	.00268	-.00309
3	.01124	.01403
4	.00790	-.02031
5	.02377	-.00087
Power Spectrum		
2	.00096	.00470
3	-.01765	-.00264
7	-.04025	.04277
8	.01113	-.02755
Position Constant	2.26673	-.12566

Table II

Group Means

Group	X	Y
P Wave	-.61434	-.75516
Baseline	1.85221	.42875
T Wave	-2.10589	1.61141

Table III

Candidate Selection

ECG Record	Actual P Waves	P Wave's Nearest Group Mean		
		P Wave	T Wave	Baseline
1	11	4	7	0
2	13	12	1	0
3	12	11	1	0
4	9	8	1	0
5	8	0	0	8
6	17	16	0	1
7	9	6	0	3
8	16	16	0	0
9	12	11	1	0
10	10	9	1	0
11	12	12	0	0
12	10	5	5	0
13	13	10	2	1
14	10	9	1	0
15	10	10	0	0
16	13	9	0	4
17	12	12	0	0
18	12	10	2	0
Total	209	170(81%)	22(11%)	17(8%)

does not contain any true disassociated P wave ECG's but some of the P waves are not followed by QRS complex at the normal distance. These are caused by PVC activity or partial AV node blockage.

The candidate selection performance is listed in Table III. The P wave is scored as selected if a section containing more than 60% of the P wave is selected as a candidate. The P wave selection rate is 81% which is approximately the rate that the BMD07M program achieved on the training set.

The total algorithm performance is given in Table IV. If two adjacent sections are classified as P waves and they share a common waveform peak, like a P wave or a T wave, they are counted as one classification. The program correctly located 58.85% of the P waves and had approximately one false classification every two and one half P wave cycles. Figure 10 shows a display from ECG record 13 in which the candidate selection failed and classified the P waves as T waves. Figure 11 shows a display from ECG record 5 in which the P waves were classified as member of the baseline group. Figure 12 shows a display from ECG record 3 where the period test failed a true P wave because a PVC covered the previous P wave. Figures 13 and 14 show displays from ECG records 13 and 14 respectively in which the P wave is located but there is no QRS complex following it. These show how the algorithm could operate on an ECG with a disassociated P wave. Figure 13 shows the location of a

Table IV

Total Classification Results

ECG Record	Actual P Waves	P Waves Located	Incorrectly Classified as a P Wave		
			T Waves	Other Waveforms	Total
1	11	2	0	10	10
2	13	9	3	0	3
3	12	9	2	3	5
4	9	5	2	1	3
5	8	0	3	1	4
6	17	11	6	0	6
7	9	3	1	0	1
8	16	15	7	4	11
9	12	9	3	0	3
10	10	7	0	2	2
11	12	8	2	0	2
12	10	2	3	1	4
13	13	5	3	0	3
14	10	8	2	6	8
15	10	10	0	0	0
16	13	1	11	0	11
17	12	10	2	0	2
18	12	9	4	1	5
Total	209	123(58.85%)	54	29	83

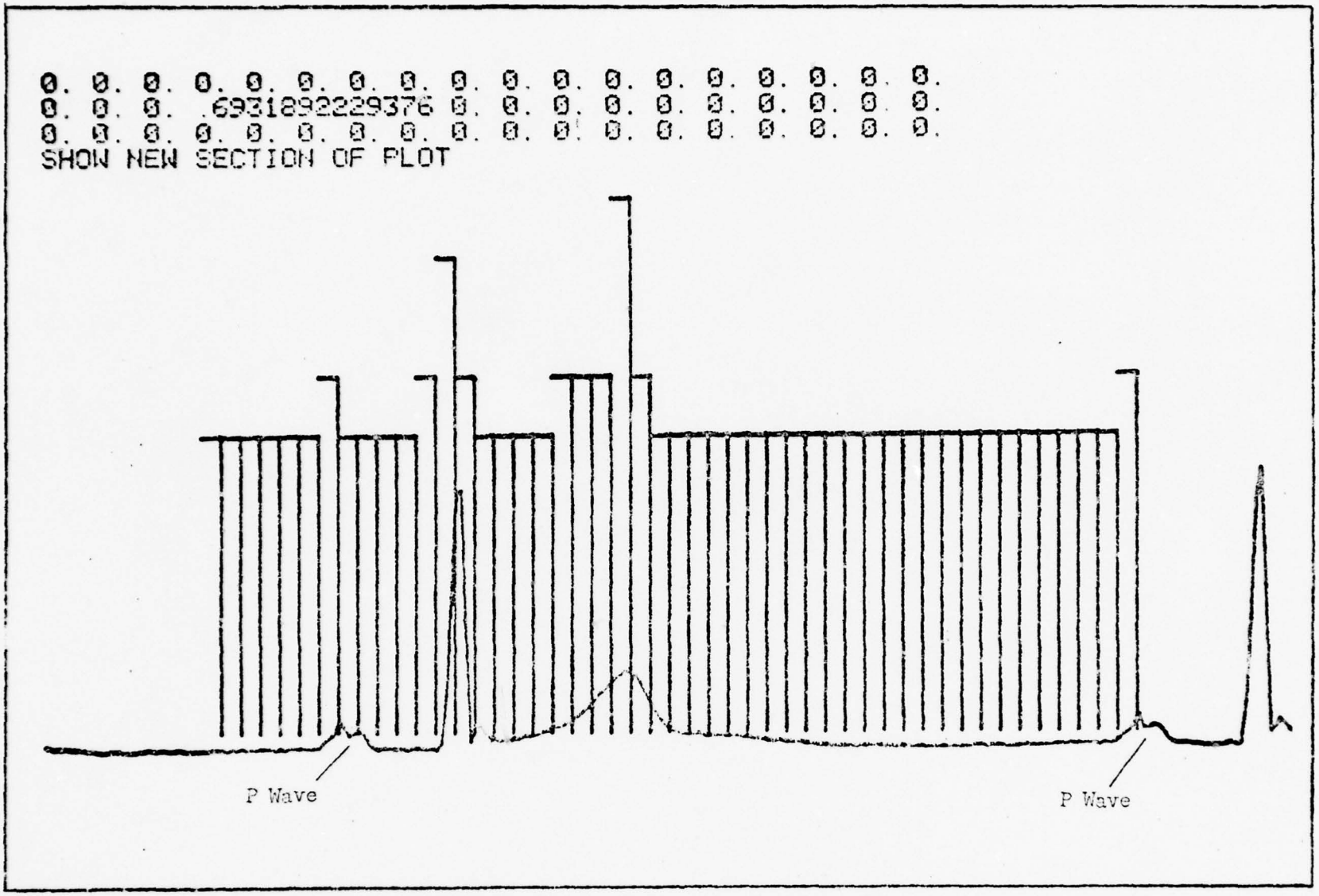

Figure 10. Analysis: ECG Record 13

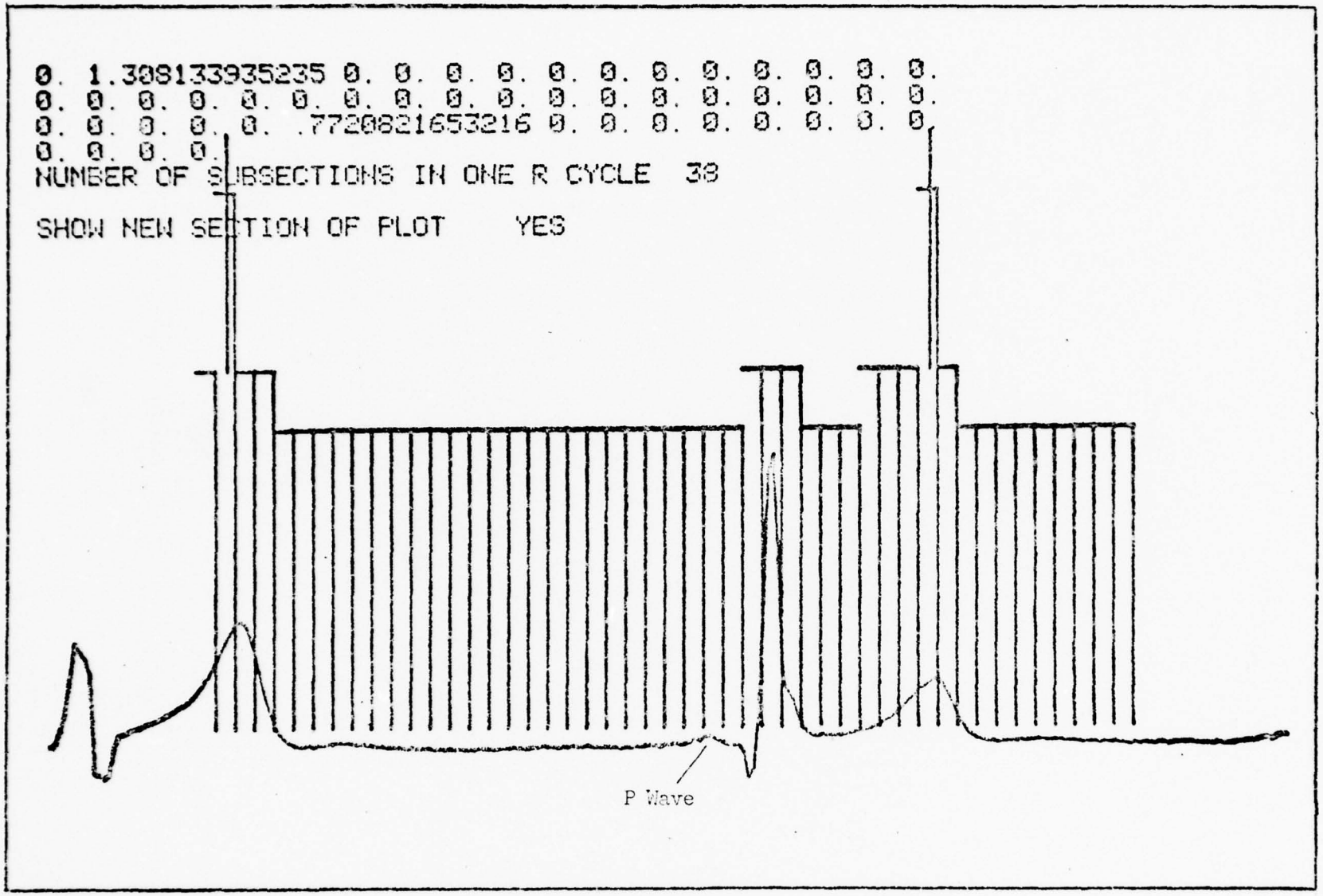

Figure 11. Analysis: ECG Record 5

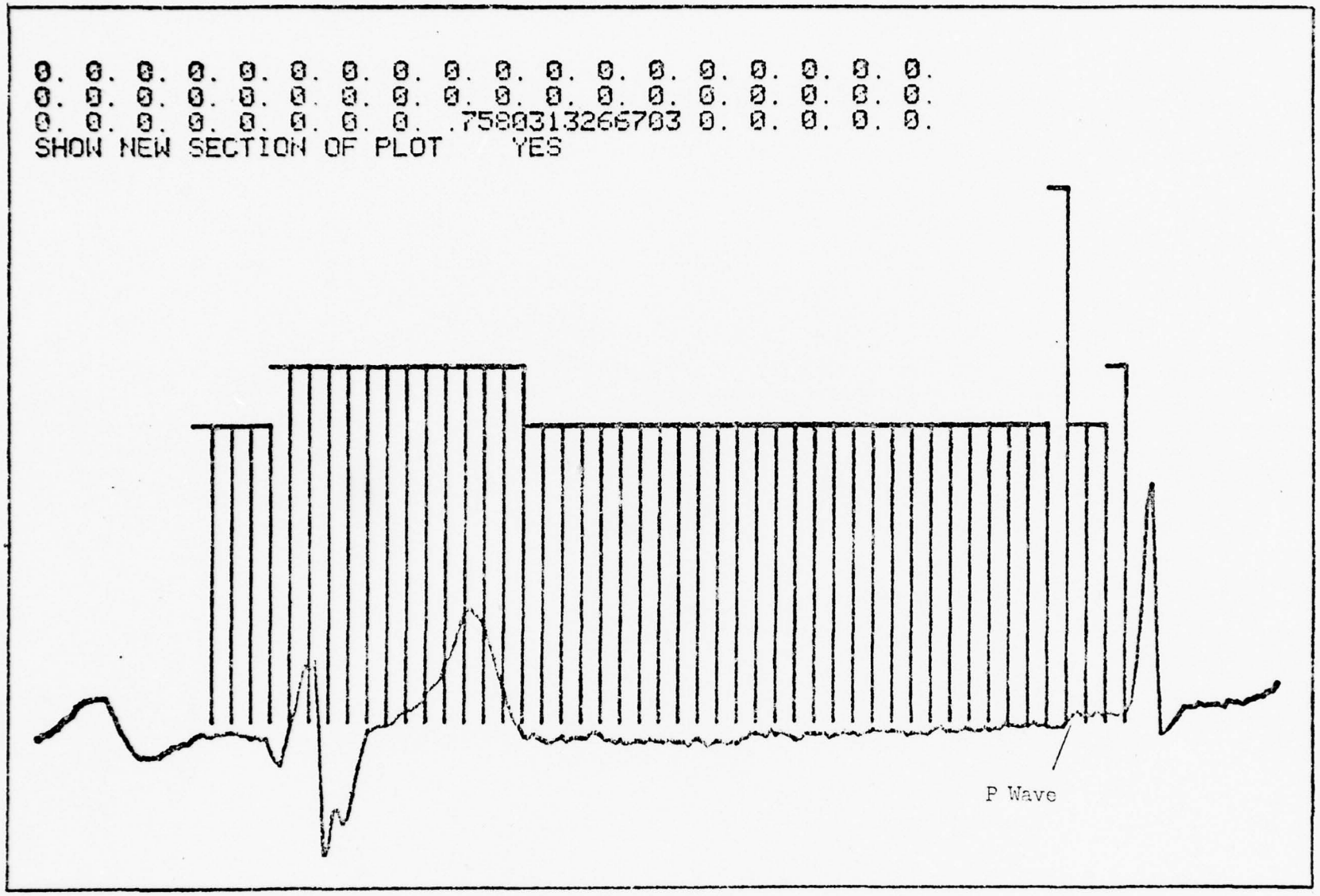

Figure 12. Analysis: ECG Record 3

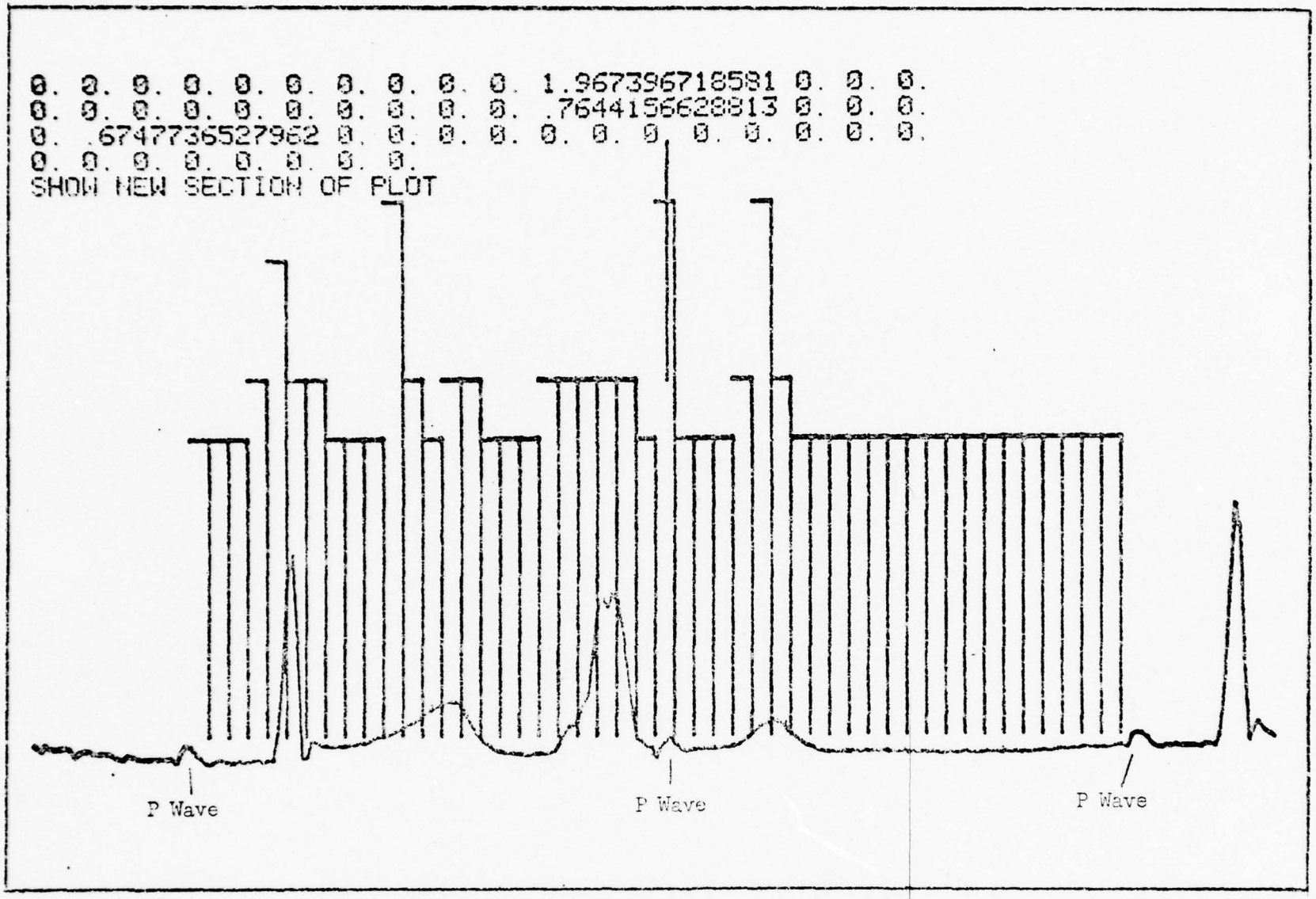

Figure 13. Analysis: ECG Record 13

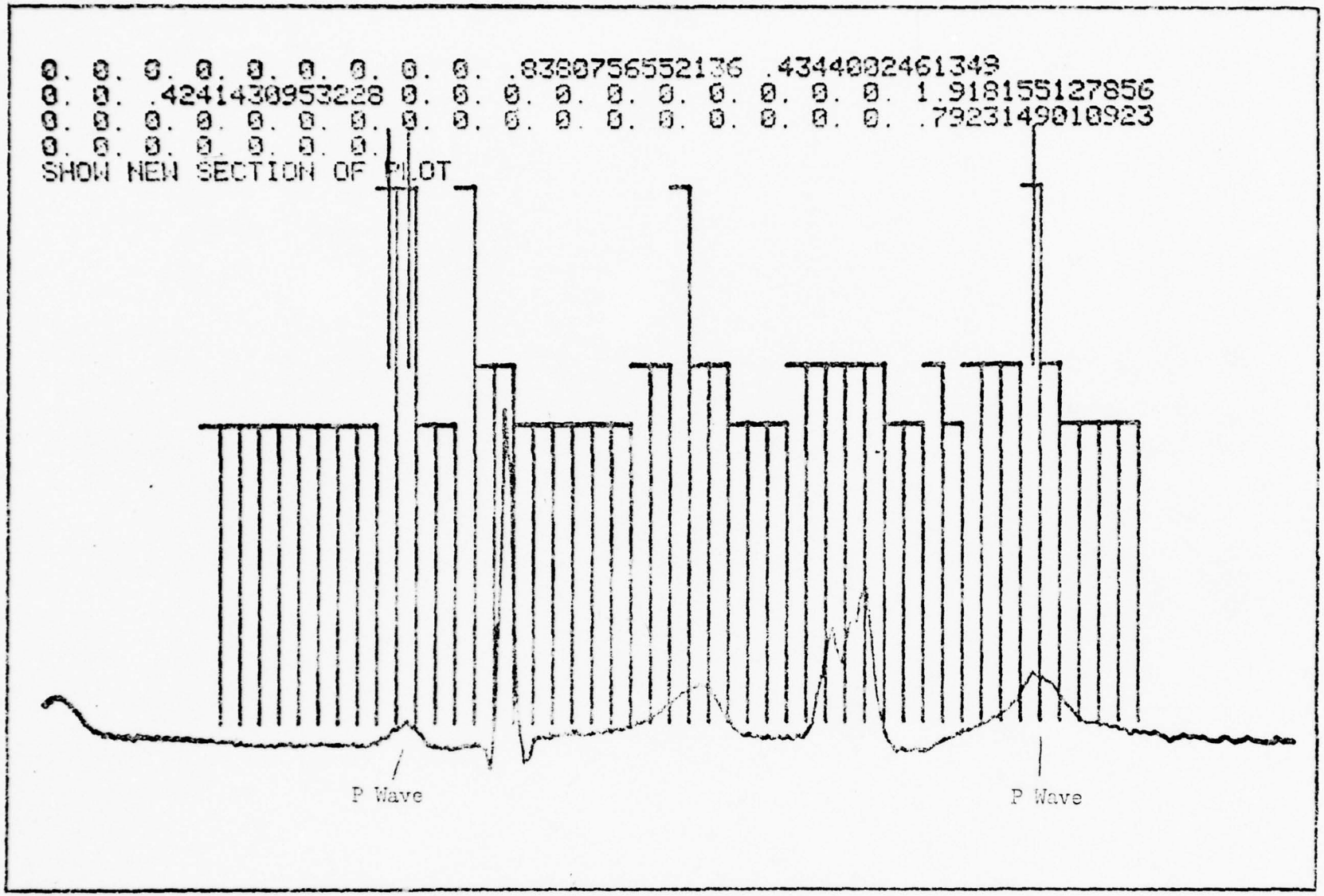

Figure 14. Analysis: ECG Record 14

P wave that occurs during a PVC. The PVC prevents the normal occurrence of the QRS complex following the P wave. Figure 14 also shows the location of a P wave during PVC activity. The shape of the second P wave is distorted by the depolarization of the heart following the PVC.

V. Conclusions and Recommendations

Conclusions

The algorithm is not reliable enough to provide useful P wave location information. The selection of a training set to be used to initialize the program for all ECG's is not a reliable method of training the classifier. The histogram period test is reliable where the P wave is not covered by a high energy wave.

Recommendations

The program can be improved in two ways: individual initialization and extended period test. One problem is the extreme variation of the P wave shape between patients and the similarity of some P waves and T waves. This is demonstrated by the results of ECG records 1, 2, 12 and 16. The program located less than 20% of the P waves in these records. This problem could be solved by training the candidate selection using the initialization algorithm with data from only the ECG to be monitored (Ref 4). Using the algorithm in this thesis would require the operator to select P waves from the ECG to initialize the program.

The period test does not classify a P wave correctly if the previous P wave was not located because it was covered by a PVC or other waveform. The program must be able to locate the P wave under these conditions to be reliable on disassociated P wave ECG's. There are two methods to improve the period test. The candidates could

be retroactively classified if they are followed by a candidate at the proper time. The second way would be to have an additional test that looked back two or more P wave periods to check for candidates in a window.

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APPENDIX A

Samples of ECG Recordings

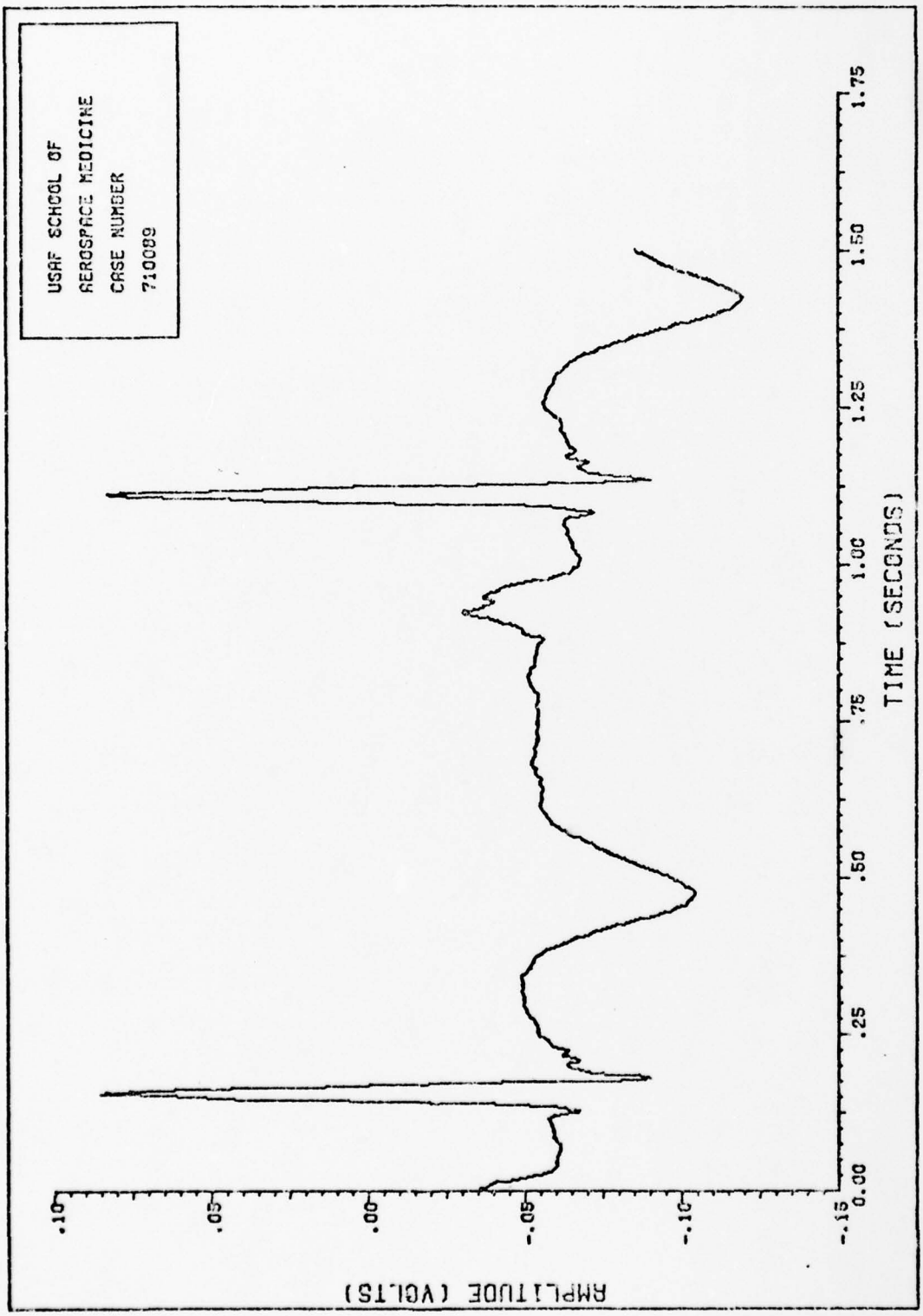

Figure 15. ECG Record 1

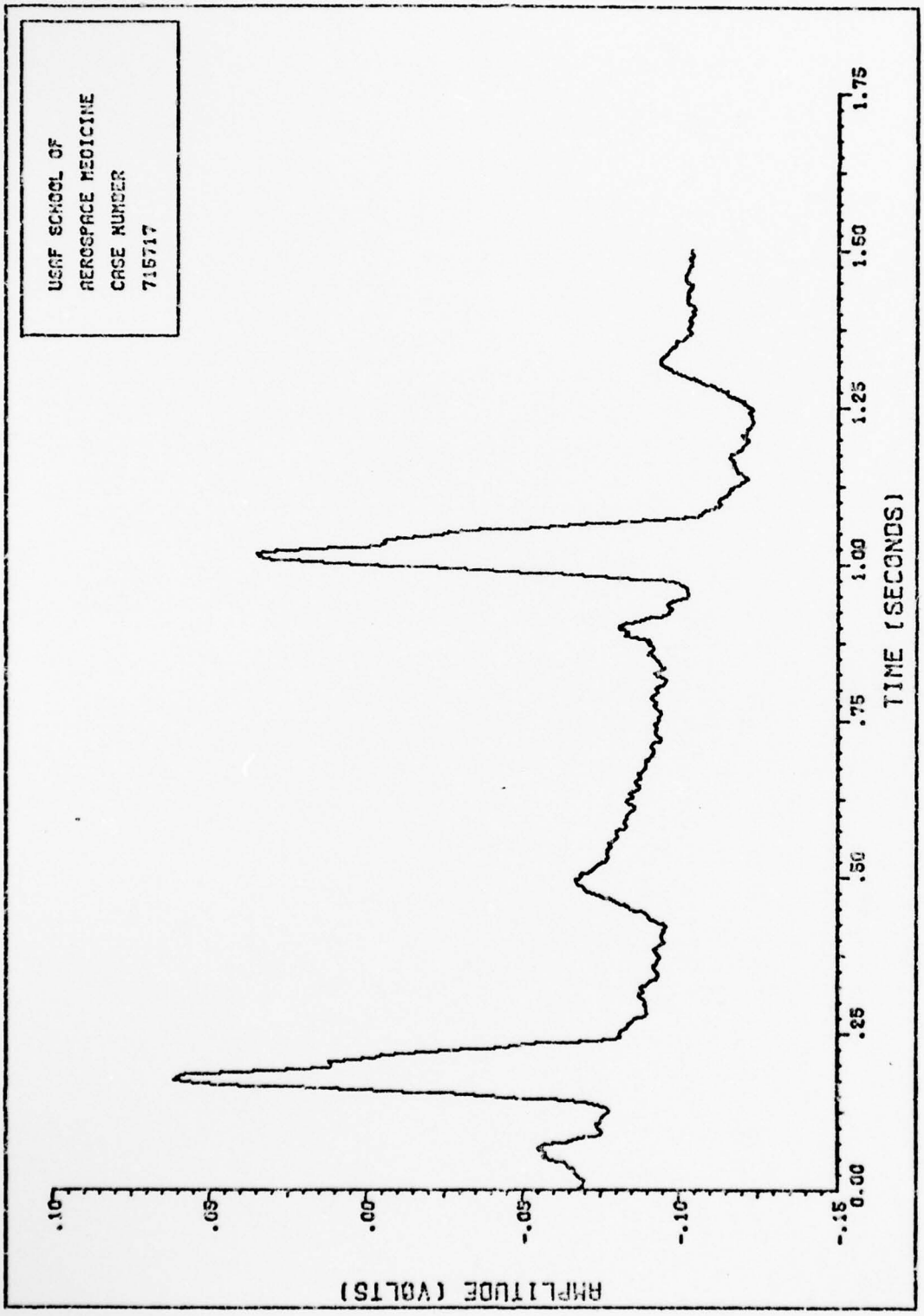

Figure 16. ECG Record 2

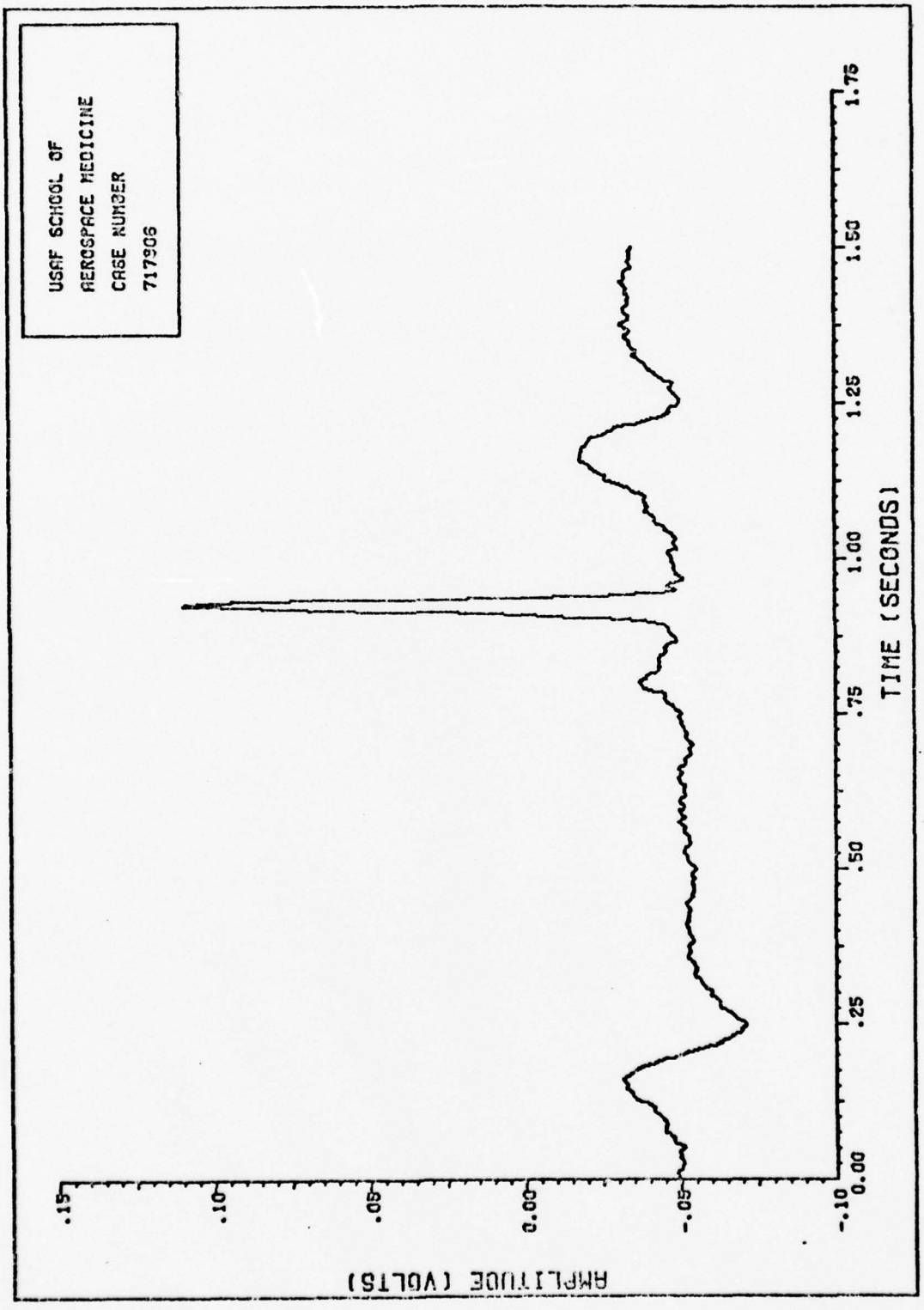

Figure 17. ECG Record 3

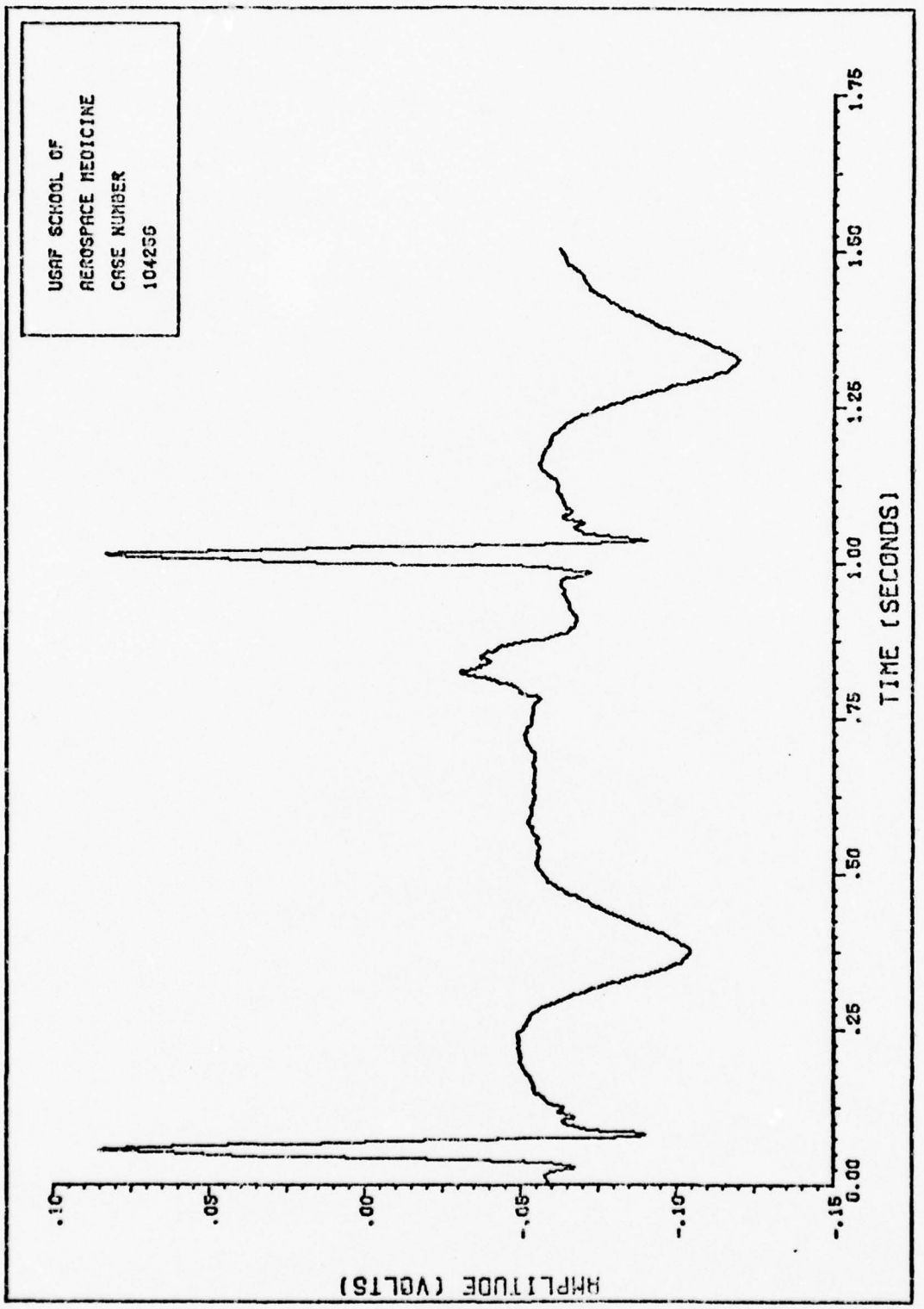

Figure 18. ECG Record 4

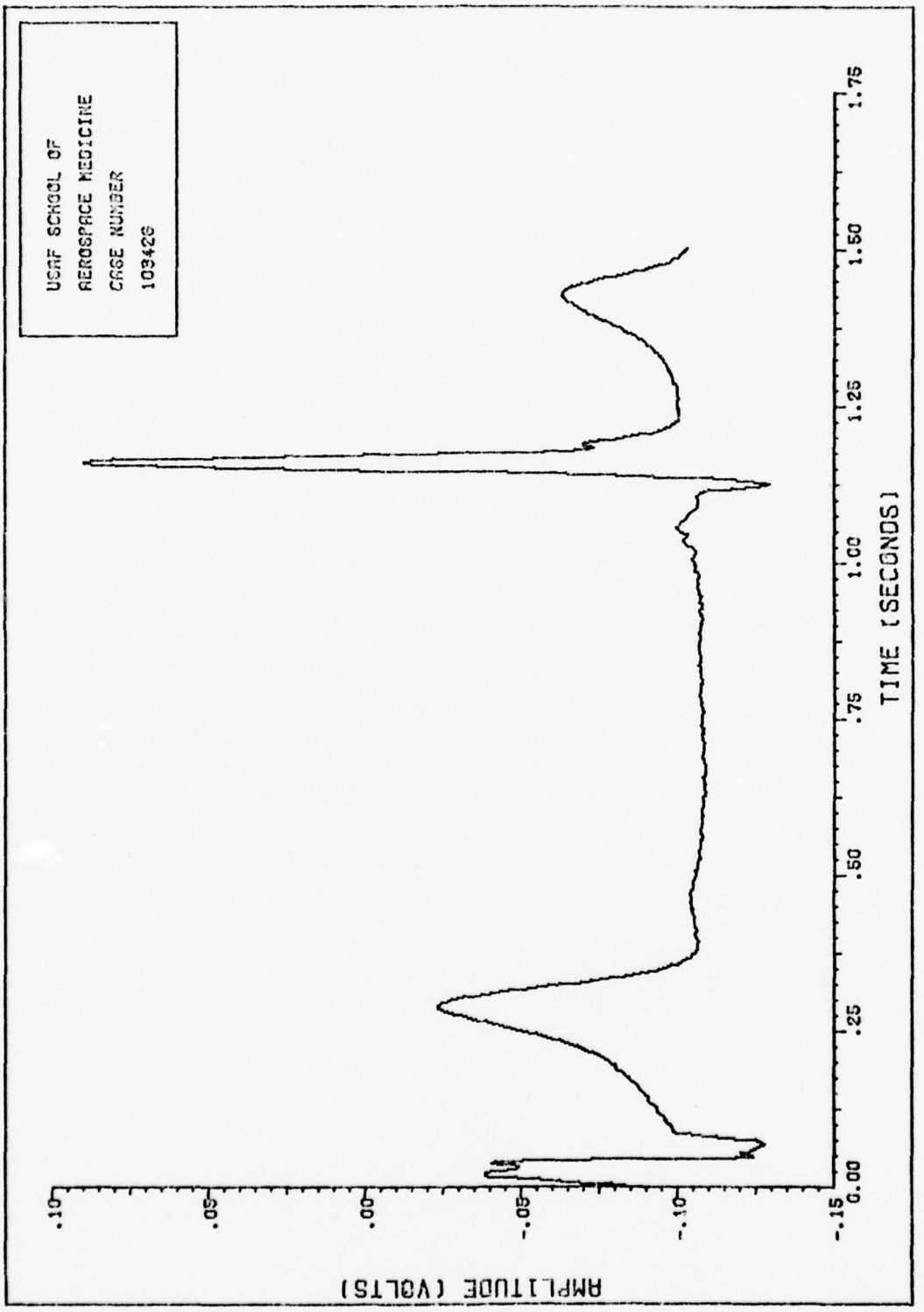

Figure 19. ECG Record 5

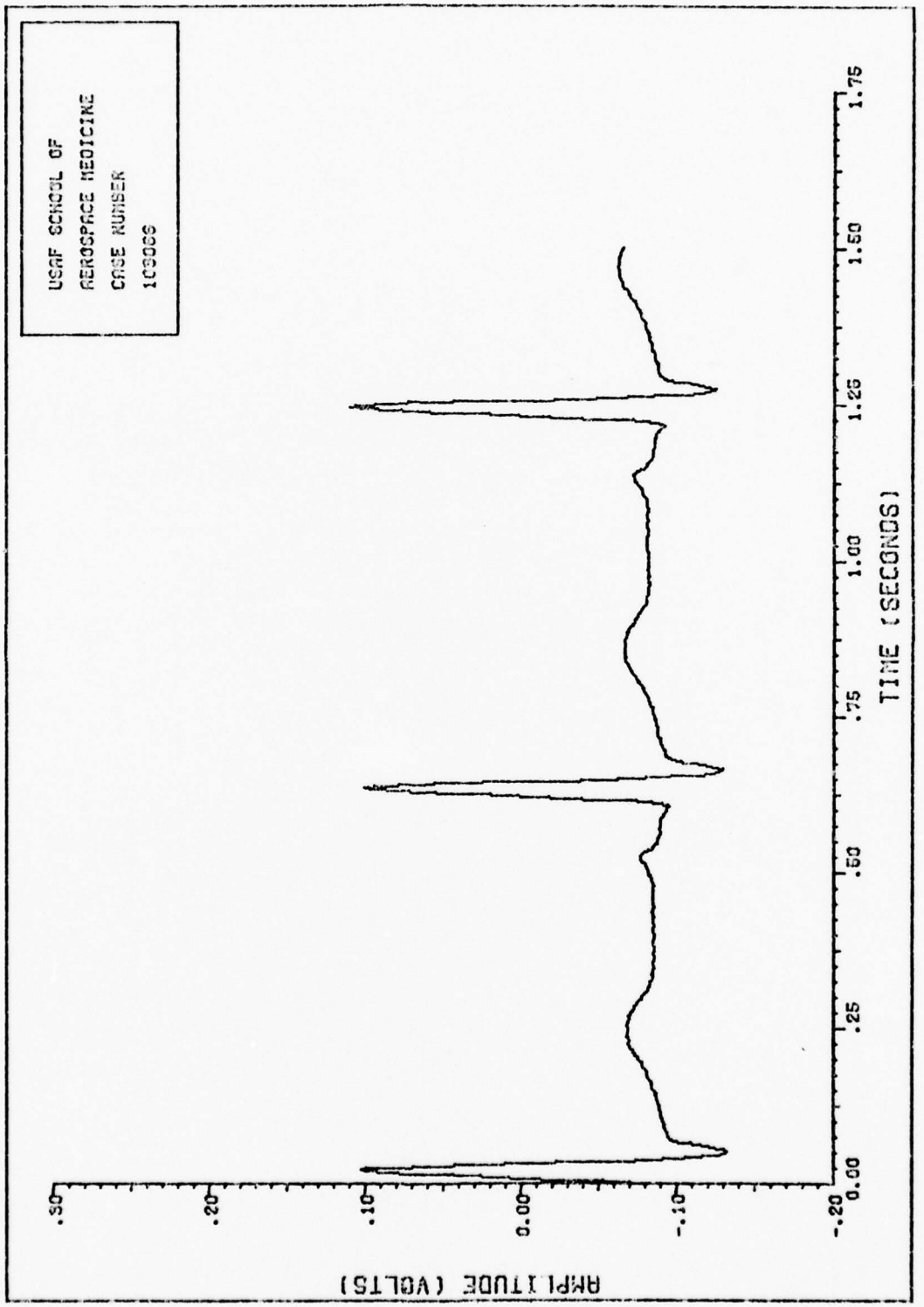

Figure 20. ECG Record 6

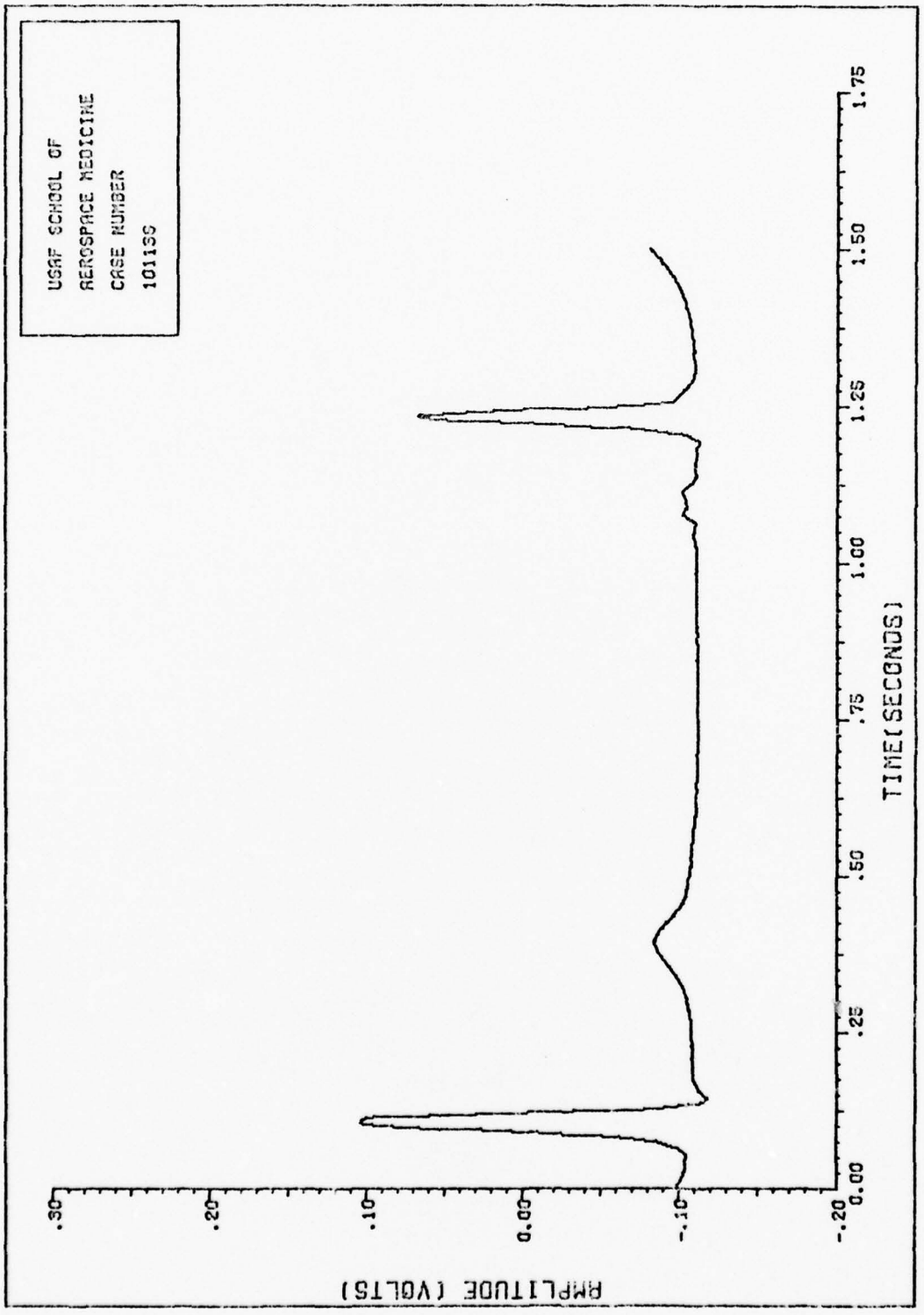

Figure 21. ECG Record 7

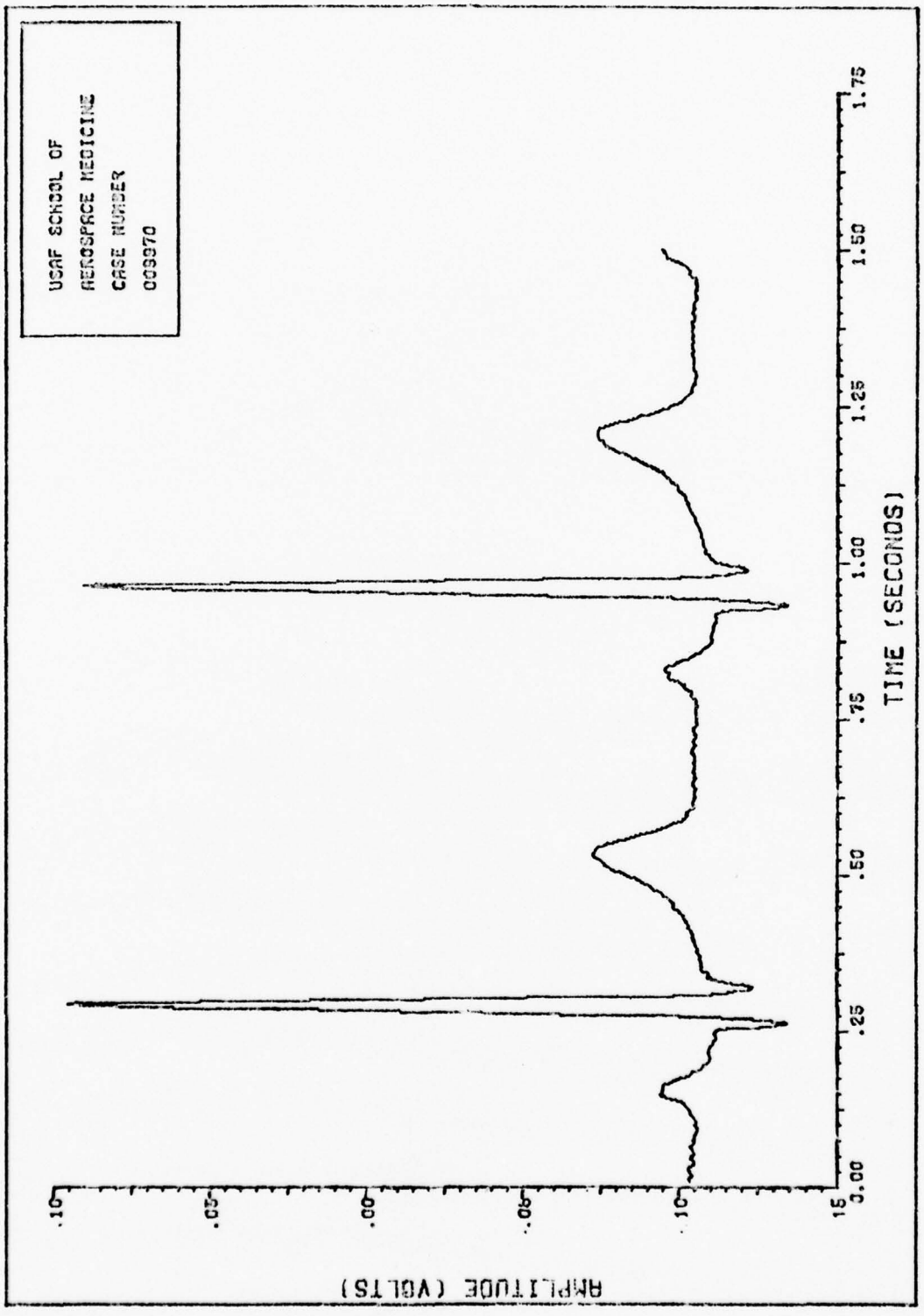

Figure 22. ECG Record 8

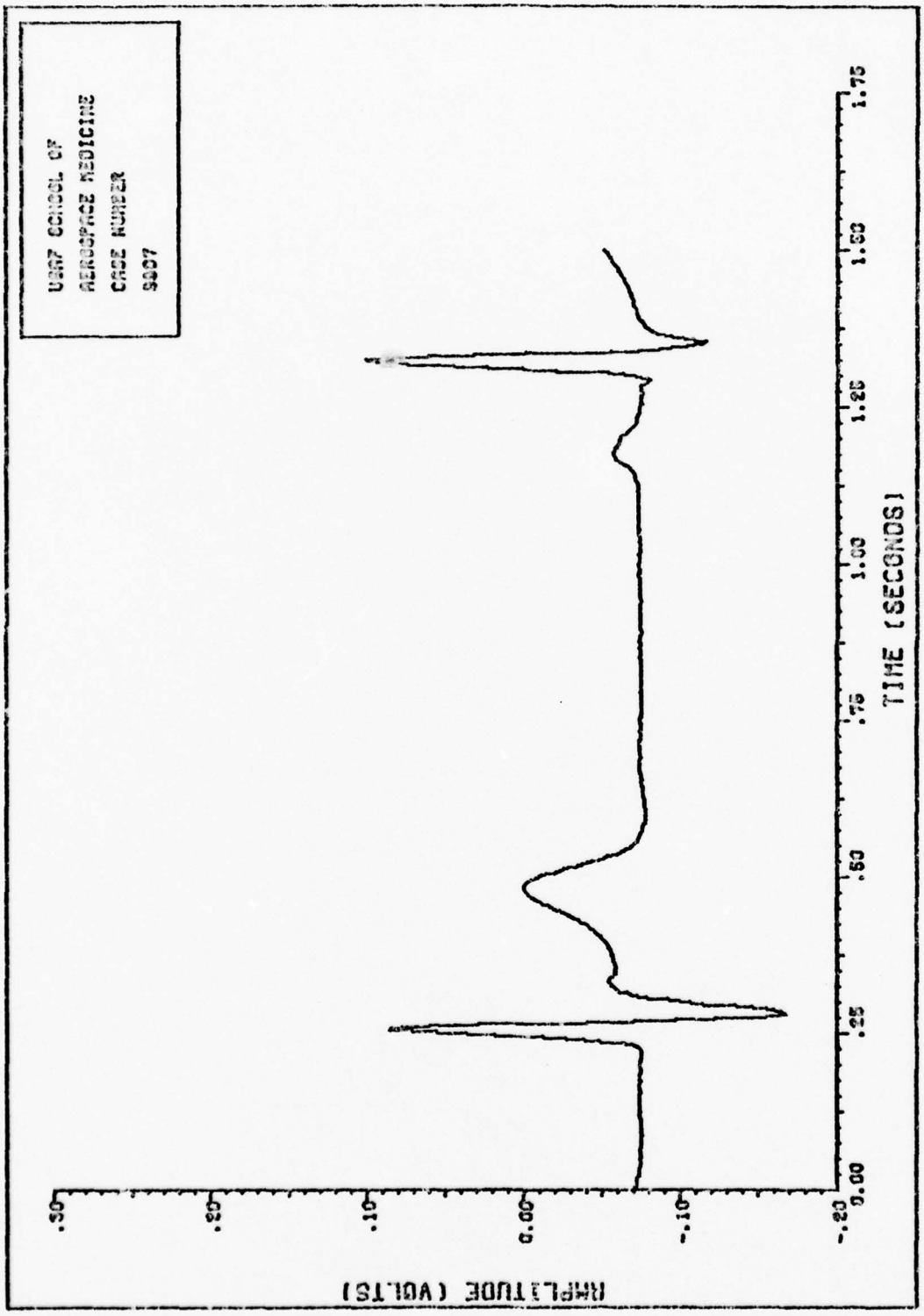

Figure 23. ECG Record 9

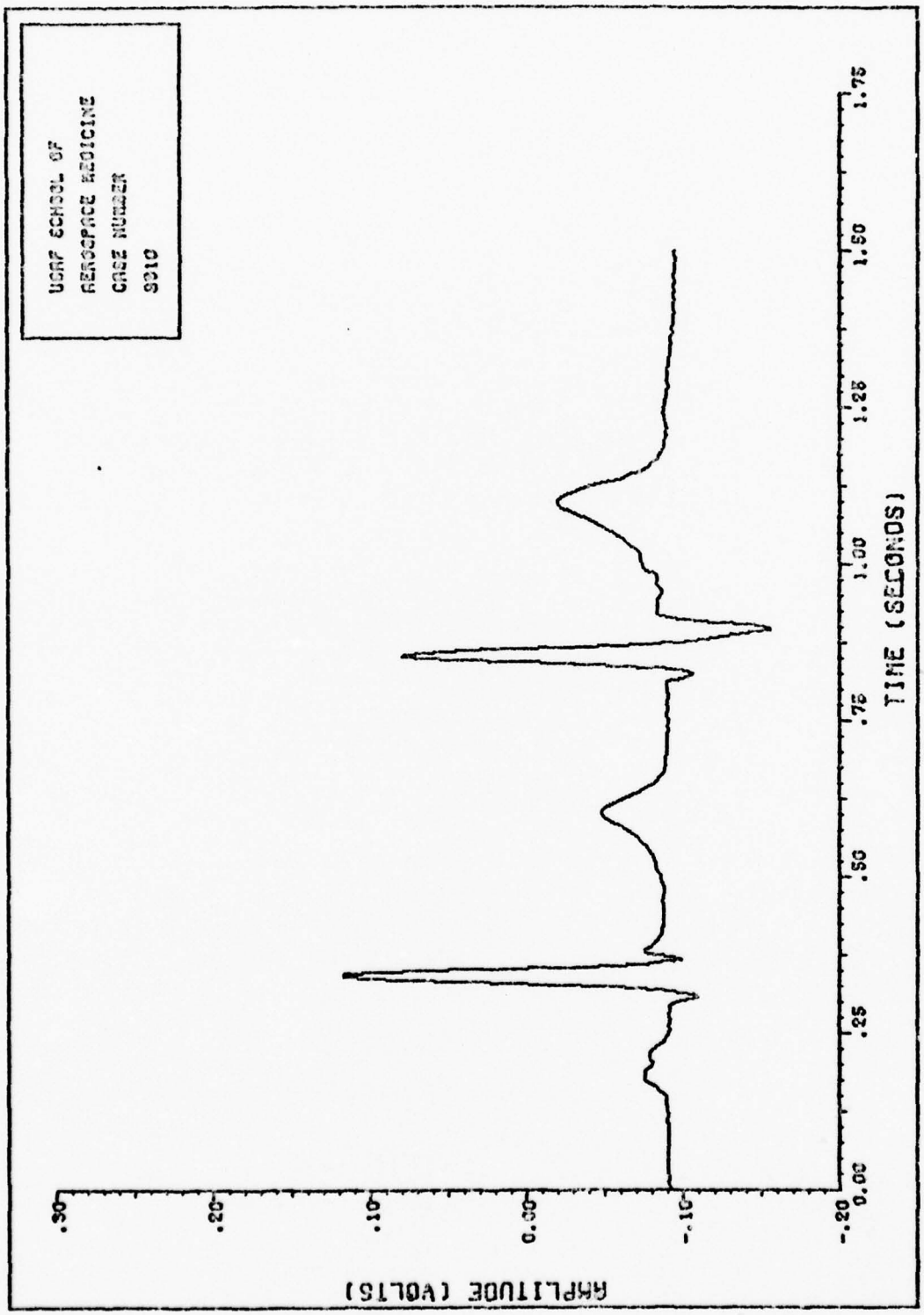

Figure 24. ECG Record 10

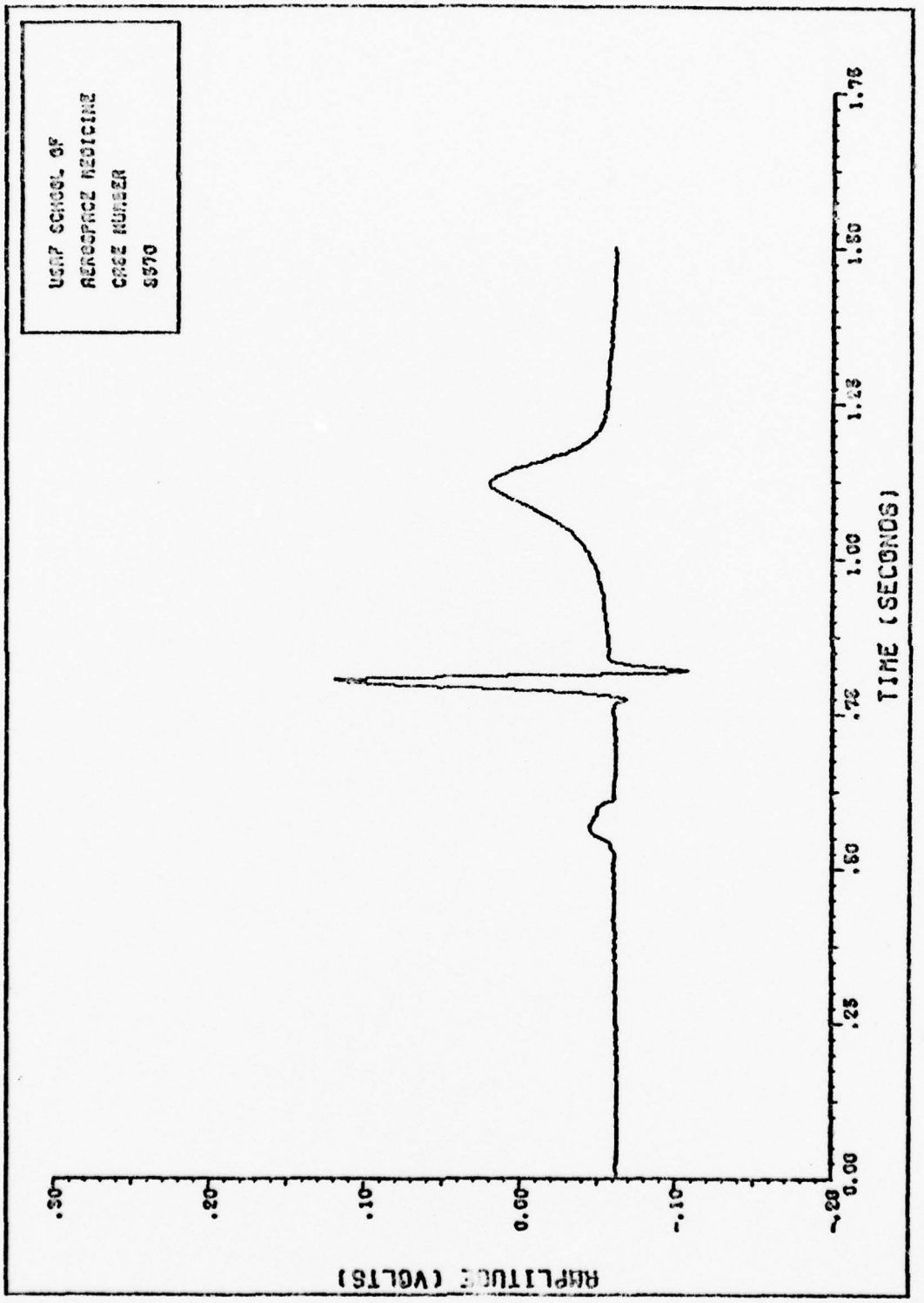

Figure 25. ECG Record 11

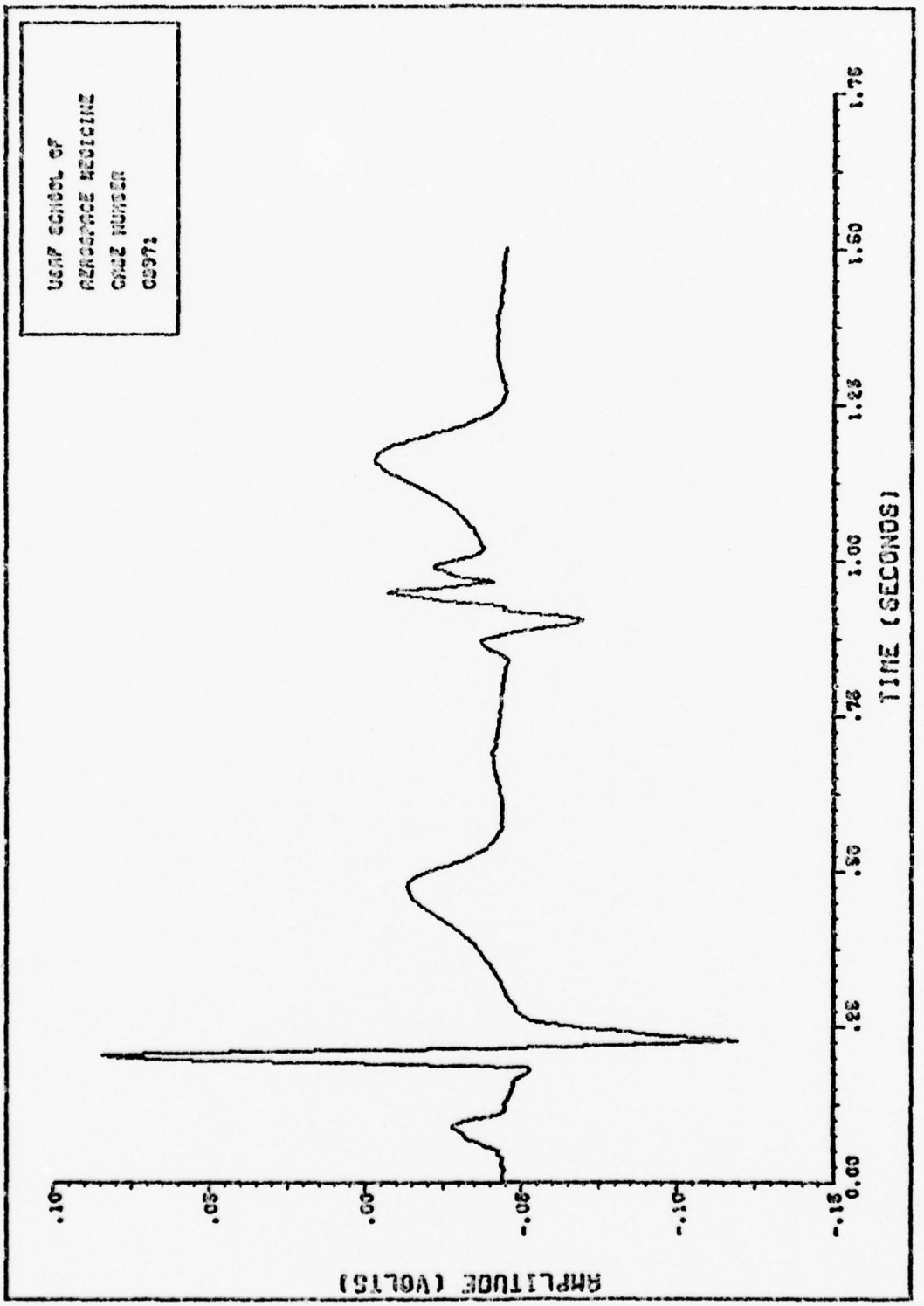

Figure 26. ECG Record 12

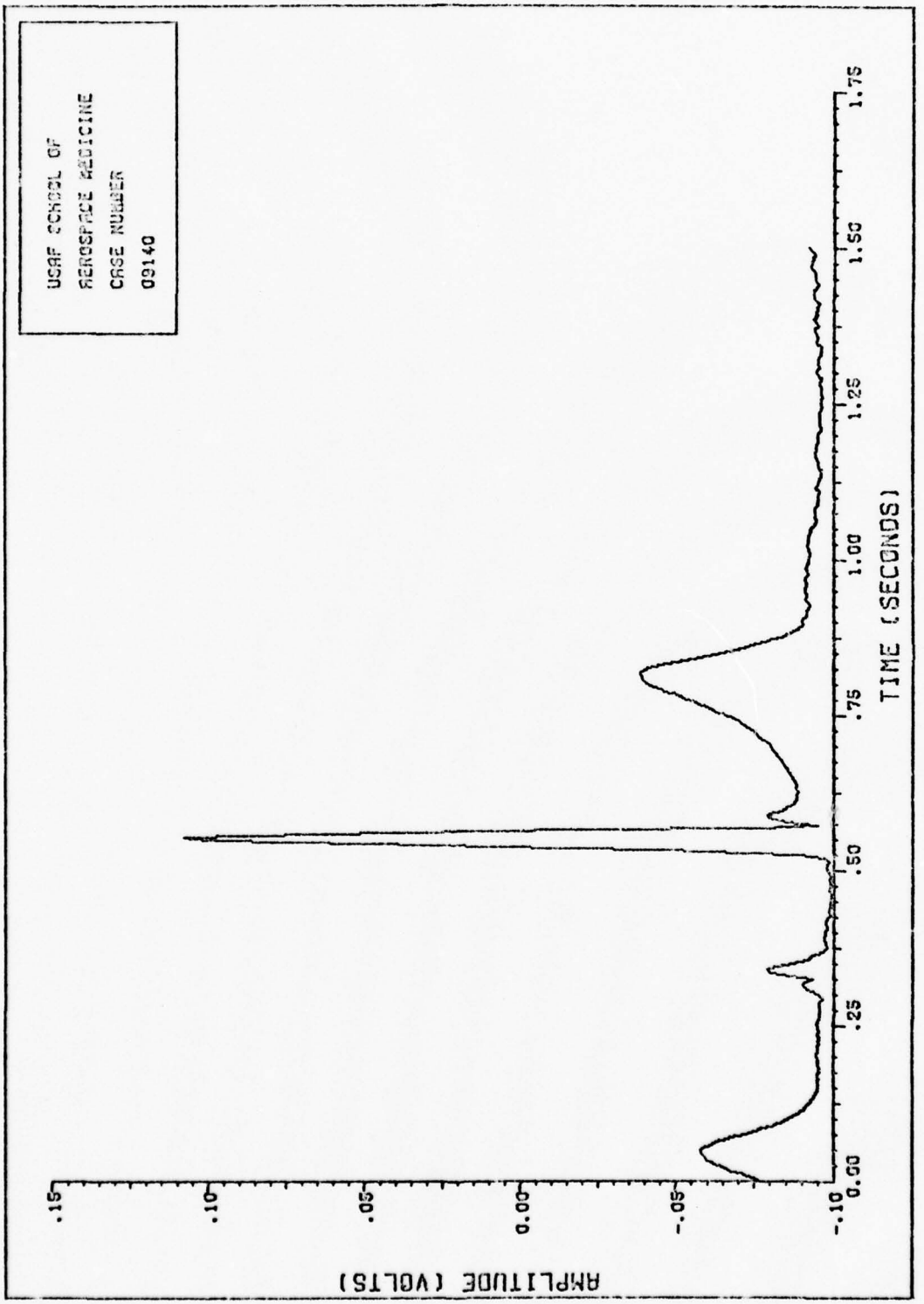

Figure 27. ECG Record 13

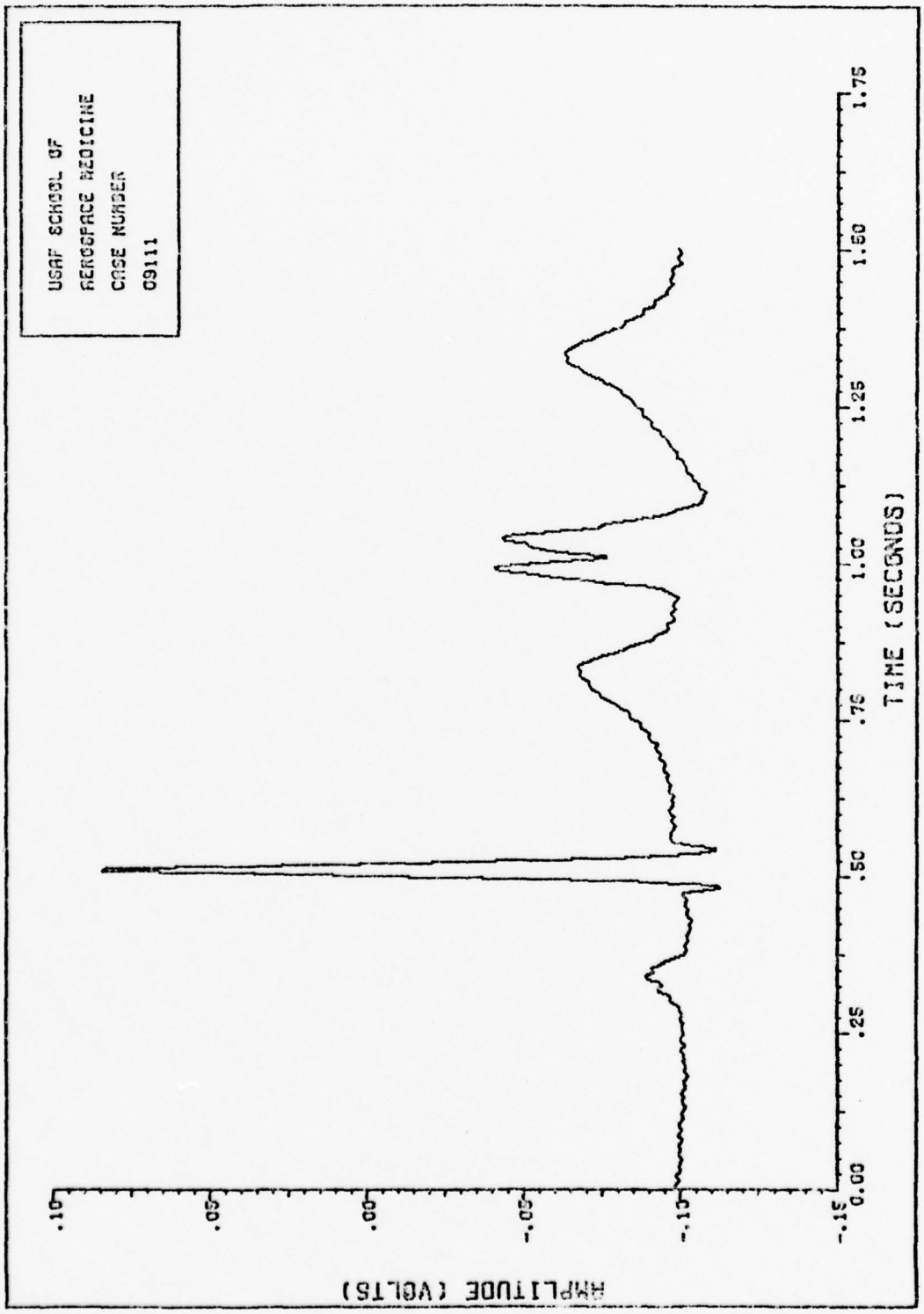

Figure 26. ECG Record 14

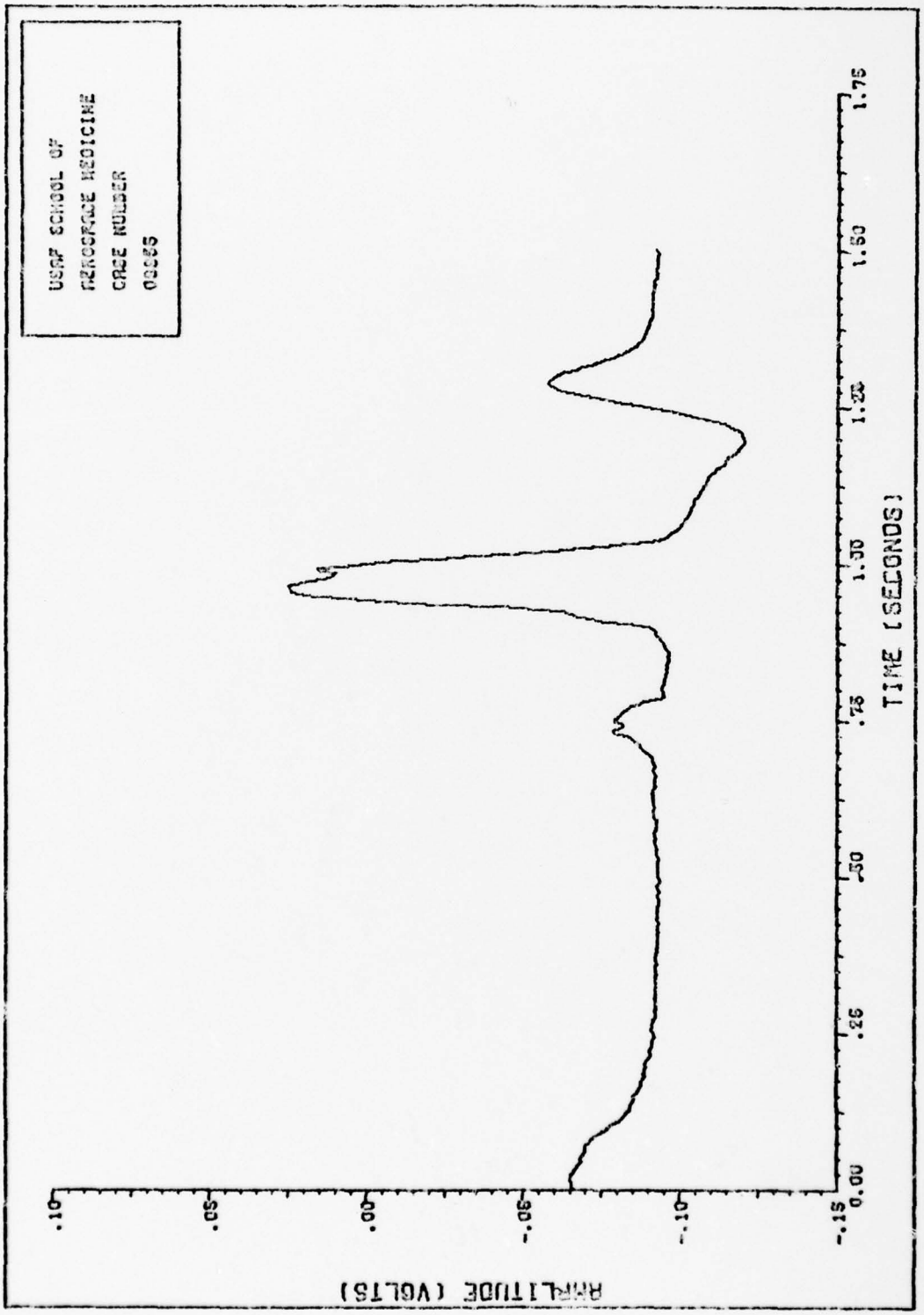

Figure 29. ECG Record 15

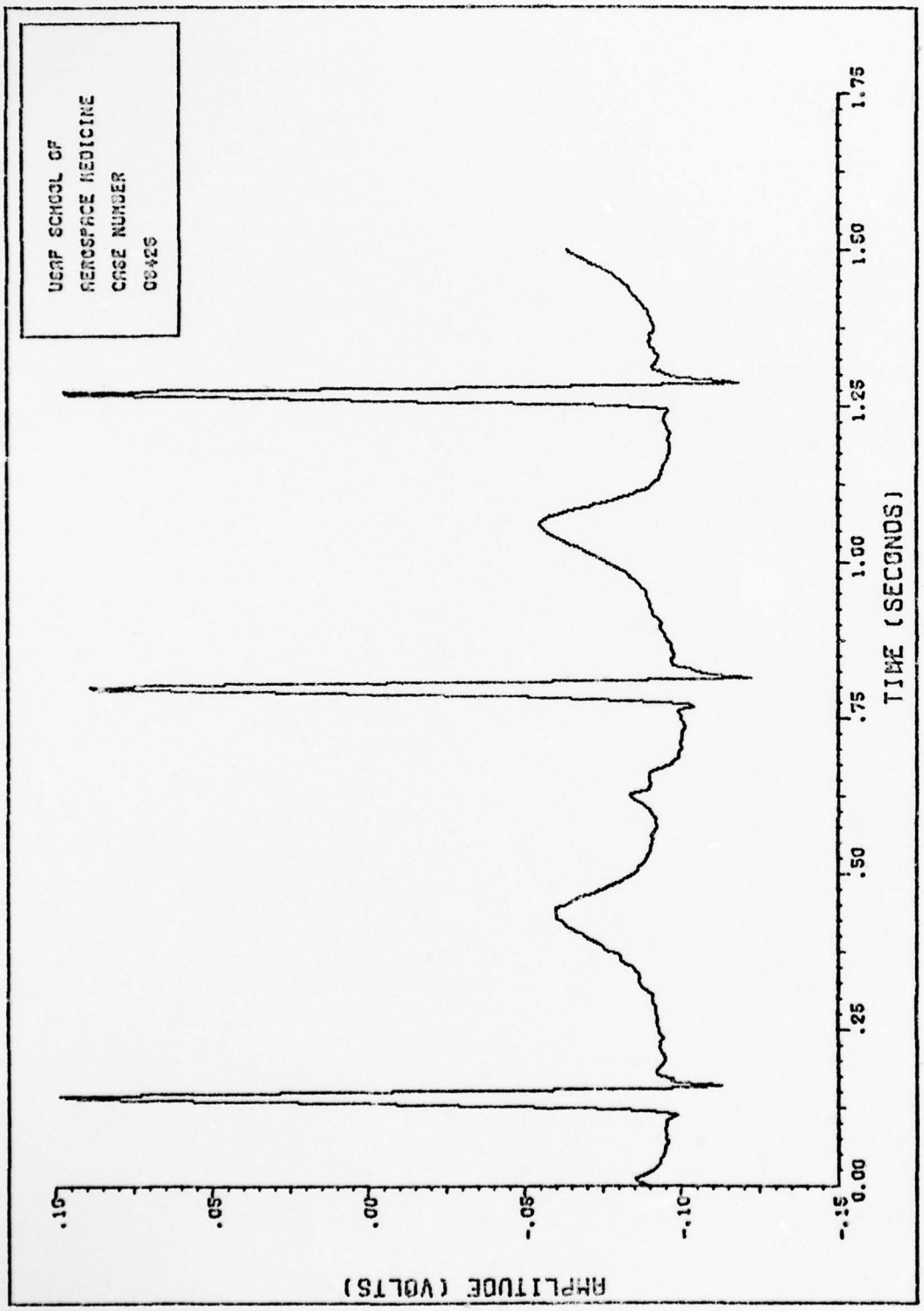

Figure 30. ECG Record 16

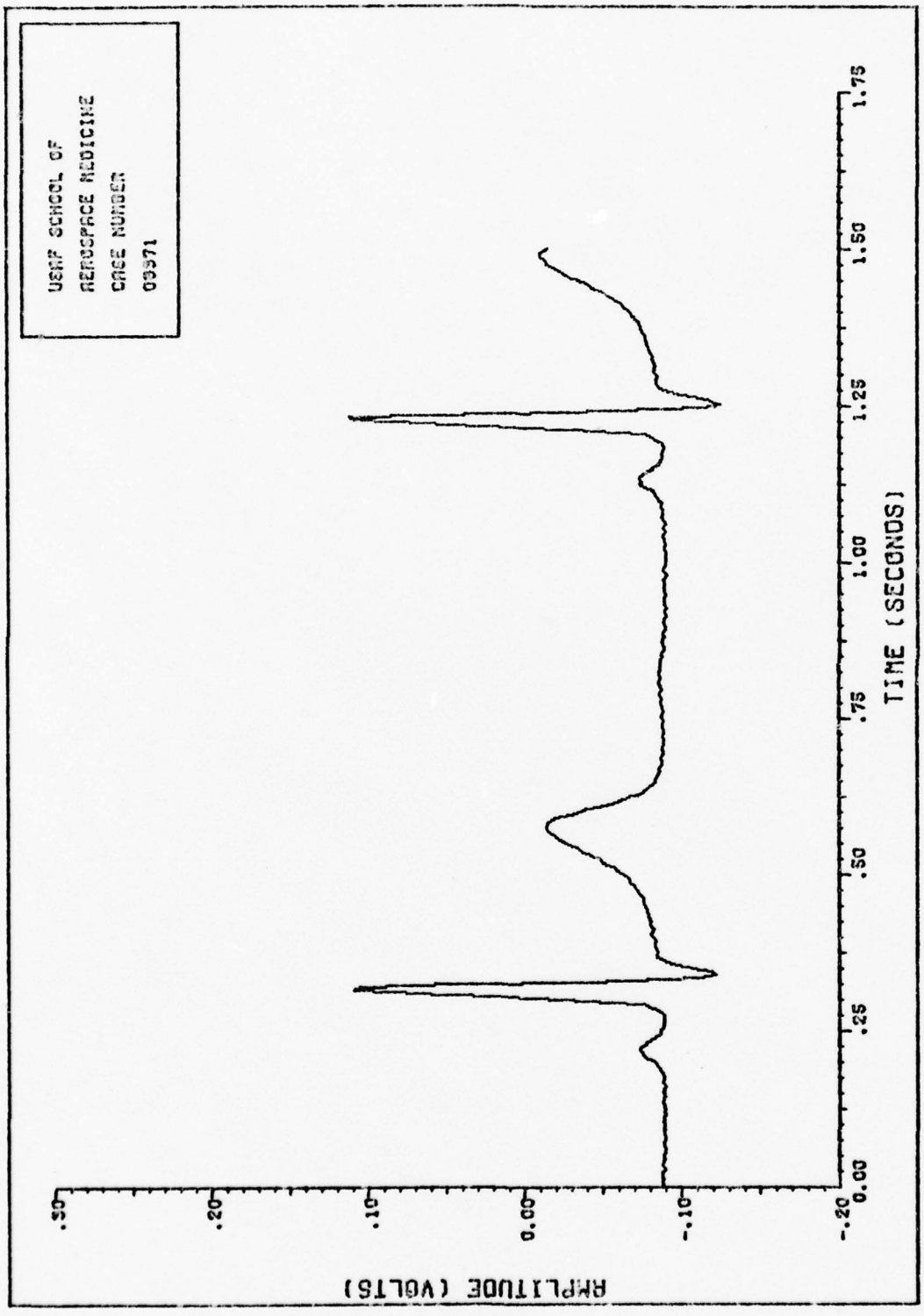

Figure 31. ECG Record 17

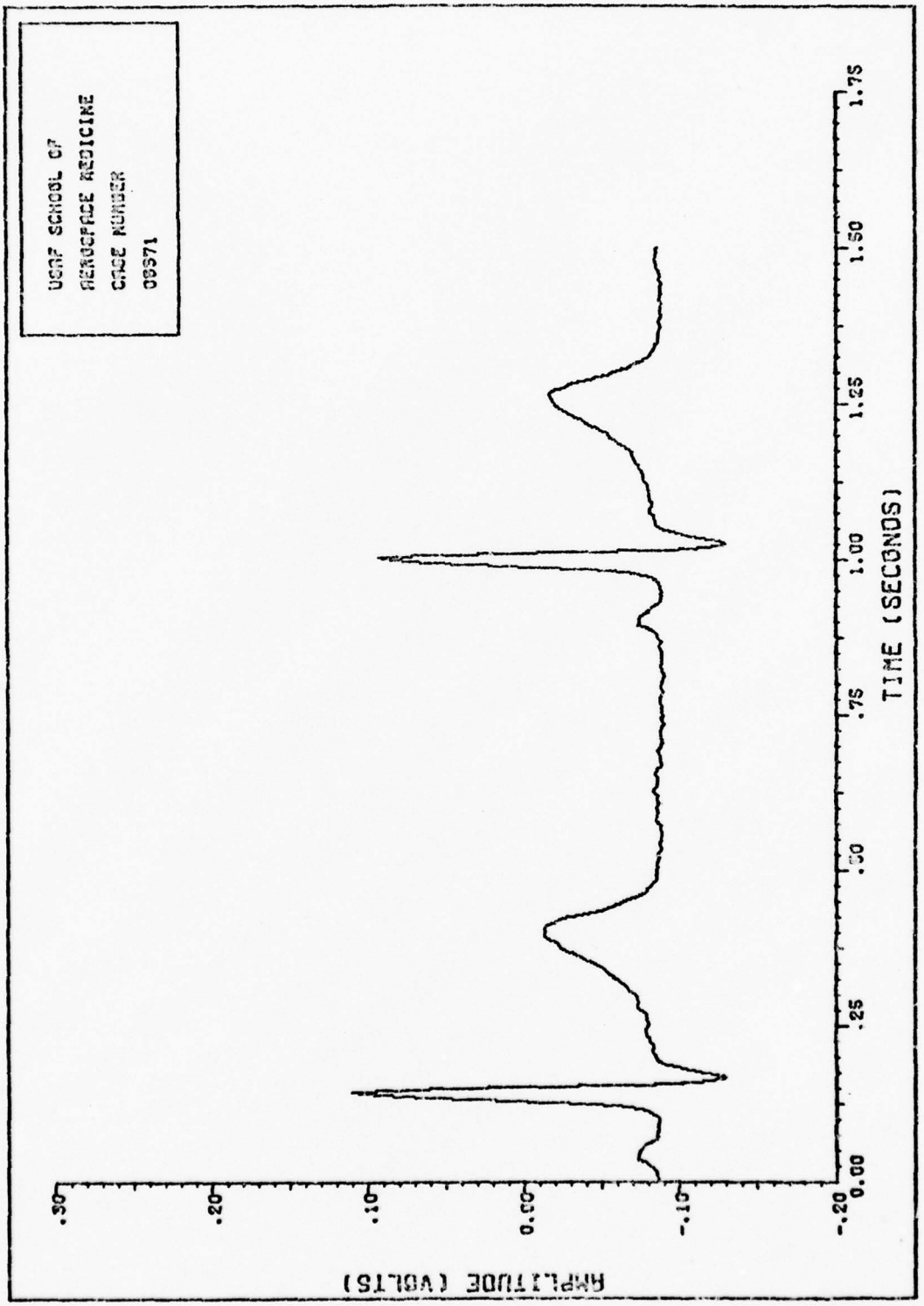

Figure 32. ECG Record 18

APPENDIX B

Computer Programs

Program to Transfer Data from Magnetic Tape to Permanent File

```
CAF,NTI.
FTN.
REQUEST,TAPE2,*PF.
REQUEST,TAPE1,HO,S,NT,VSN=XJ3969,MOPING.
CATALOG,TAPE2,CDATA.
LGO.
"
C*****************************************************************
C         PROGRAM TO STORE DATA FROM MAG TAPE
C         TO PERMINATE FILE.  INPUT USING BUFFER
C         IN A 481 WORD BLOCK SIZE AND OUTPUT
C         USING UNFORMATTED WRITE.
C*****************************************************************
      PROGRAM STORE(INPUT,OUTPUT,TAPE1,TAPE2)
       DIMENSION INDATA(960)
      IFILE=1
5     CONTINUE
      IREC=1
10     BUFFER IN (1,1) (INDATA(1),INDATA(960))
      IF(UNIT(1)) 10,20,25
15     WRITE (2) INDATA
      IREC=IREC+1
      GO TO 10
C
20     ENDFILE 2
      PRINT*,"FILE ",IFILE," HAS ",IREC," RECORDS"
      IF(IFILE.EQ.10) GO TO 25
      IFILE=IFILE+1
      GO TO 5
25    STOP
      END
```

Program to Separate the X Component of the ECG

```
CAF,T90.
FTN,R=3,OPT=2.
REQUEST,TAPE2,*PF.
ATTACH,TAPE1,ODATA.
LGO.
CATALOG,TAPE2,DATA,RP=999
C*****************************************************************
C          PROGRAM TO UNPACK 16 BIT WORDS FROM 60
C          BIT STORAGE WORDS. READ UNFORMATED FROM
C          TAPE1 AND WRITE IN 16F4.0 FORMAT
C*****************************************************************
      PROGRAM DECODE(INPUT,OUTPUT,TAPE1,TAPE2)
      DIMENSION INDATA(480),JMASK(3),KMASK(3),DATA(1920)
      DIMENSION XDATA(16)
      MASK=177777B
C*****************************************************************
C       MASKS FOR END OF WORD
C*****************************************************************
      JMASK(1)=177760B
      JMASK(2)=177700B
      JMASK(3)=170000B
C*****************************************************************
C       MASKS FOR THE BEGINNING OF NEXT WORD
C*****************************************************************
      KMASK(1)=17B
      KMASK(2)=1777B
      KMASK(3)=77777B
C
      IFILES=1
      IREC=-76
      L=1
10    K=1
C*****************************************************************
C       INPUT ONE BLOCK OF DATA TO ARRAY INDATA
C*****************************************************************
      IF(EOF(1).NE.0)GO TO 24
      READ(1) INDATA
C*****************************************************************
C          PLACE 16 BIT INTEGERS INTO ARRAY DATA
C*****************************************************************
      DO 100 I=1,480
      KA=(SHIFT(INDATA(I),6*K-4))
            DO 200 J=1,3
            KA=SHIFT(KA,16)
            KK=MASK.AND.KA
            DATA(L)=KK
            L=L+1
```

```
2.0           CONTINUE
              IF(K-4) 120,300
123     KC=SHIFT(INDATA(I+1),4*K).AND.KMASK(K)
              KA=SHIFT(KA,16).AND.JMASK(K)
              KK=KA.OR.KC
              DATA(L)=KK
              L=L+1
              GO TO 400
300           K=0
400           K=K+1
100           CONTINUE
C*************************************************************
C             PLACE EVERY THIRD ELEMENT INTO AN
C             ARRAY AND THEN OUTPUT IT
C*************************************************************
134           DO 135 LM=1,16
              XDATA(LM)=DATA(LM*3-2)
          IF(XDATA(LM).GT.12[illegible])GO TO 175
          XDATA(LM)=XDATA(LM)+2**15
135           CONTINUE
          IF(IREC.LT.0) GO TO 139
          WRITE(2,600) XDATA
139       CONTINUE
600       FORMAT(16F6.0)
          IREC=IREC+1
C
          L=L-48
              DO 140 KM=1,1300
              DATA(KM)=DATA(KM+48)
140           CONTINUE
          IF(L.GE.48)GO TO 134
          GO TO 18
C
200        ENDFILE 2
          L=1
          PRINT*,"FILE ",IFILES," HAS"," " ,IREC," RECORDS"
          IREC=-76
          IFILES=IFILES+1
          IF(IFILES.GT.17) GO TO 30
          GO TO 18
30         STOP
           END
```

Program to Locate Prototypes

```
C*************************************************************
C       PROGRAM TO INTERACTIVELY LOCATE PROTOTYPES AND
C        EXAMINE THEIR FOURIER DOMAIN VALUES
C*************************************************************
C*************************************************************
C        COMMANDS TO ATTACH NEEDED FILES
C        ATTACH,T,TEKPLOT,ID=AFIT
C        LIBRARY,T
C        ATTACH,TAPE1,"DATA FILE NAME"
C*************************************************************
      PROGRAM PROTO(INPUT=132,OUTPUT=102,TAPE1,TAPE2)
      DIMENSION IDATA(1024),DATA(15),ADATA(1024)
      DIMENSION SDATA(1024)
      DIMENSION FREQEN(6)
      DIMENSION S(1 ),T(1 )
      COMPLEX FFTV(24)
      DIMENSION FVEC(20,16)
      COMMON IEXP,NUMFVC,FVEC,FFTV,ADATA,IDATA,SDATA
C*************************************************************
C        INITIALIZE CONSTANTS
C*************************************************************
      DATA S/.2,.3,1.,1.,1.,1.,1.,1.,
     1,.2,.7,.8,1.,1.,1.,1.,1.,1./
      DATA T/-100,0,1,0,0,3,0,0,0,0,0,0,0,1,0/
      ERROEXP=1
      TFILE=1
      NUMFVC=1
      PRINT*,"PROGRAM TO LOCATE PROTOTYPES"
      PRINT*,"TYPE (STOP) AT ANY YES OR NO"
      PRINT*,"QUESTION TO END PROGRAM"
      PRINT*,"PROTOTYPE SIZE ="
      READ*,I2?S7
      PRINT*,"="
      PRINT*,"DO YOU WISH TO PLOT THE FFT ",
     1"/FOUTOP,THE FREQUENCY SPECTRUM OR NEITHER"
      PRINT*,"FFT,FREQ,NONE"
      READ 603,I
603   FORMAT(A2)
      IF(I.EQ.2HFF)FREQ=0
      IF(I.EQ.2HFR)FREQ=1
      IF(I.EQ.2HNO)OUTPUT=1
C
      IDIST=1024
```

```
C*****************************************************************
C          FILL DATA ARRAY
C*****************************************************************
85      IREC=0
90      KI=1
        TIMEM=0
C*****************************************************************
C       BACKSPACE TO THE BEGINNING OF THE FILE
C*****************************************************************
92      IF(IREC.LE.0) GO TO 85
        TIMEM=0
        KI=1
        KO=1
        BACKSPACE 1
        IREC=IREC-1
        GO TO 92
95      IF(EOF(1)) 300,96
96      READ(1,601) DATA
601     FORMAT(15F5.0)
        IREC=IREC+1
        KO=1
100     SDATA(KI)=DATA(KO)
        IF(KI.EQ.IDPS7) GO TO 114
        KI=KI+1
        KO=KO+1
        IF(KO.NE.17) GO TO 100
        GO TO 95
C*****************************************************************
C    NORMALIZE MEAN
C*****************************************************************
114     SUM=0
        DO 106 JJ=1,IDPS7
106         SUM=SUM+SDATA(JJ)
        XMEAN=SUM/IDPS7
        DO 107 JJ=1,IDPS7
107         ADATA(JJ)=SDATA(JJ)-XMEAN
C*****************************************************************
C    NORMALIZE VARIANCE
C*****************************************************************
        SSUM=0
        DO 108 JJ=1,IDPS7
108         SSUM=SSUM+ADATA(JJ)**2
        SIG=SQRT(SSUM)/IDPS7
        DO 109 JJ=1,IDPS7
109         ADATA(JJ)=ADATA(JJ)/SIG
        TIMEXPAN=1
        SHIFT=200
        DO 111 JJ=1,IDPS7
111         IDATA(JJ)=TIMEXPAN*ADATA(JJ)+SHIFT
C
C
C       CALL SUBROUTINE TO PLOT ECG
        CALL PLOTECG(IDATA,IDPS7)
        CALL FINITT(11,763)
C
```

```
C
202   PRINT*,"SHOW NEW SECTION OF PLOT     "
      READ 300 ,I
      IF(I.EQ.1HY) GO TO 330
      IF(I.EQ.1HN) GO TO 103
      IF(I.EQ.1HS) GO TO 999
      PRINT*,"MUST BE YES OR NO!!!!!!"
      GO TO 202
C
103   CONTINUE
C
C     CALL SUBROUTINE TO PLOT SCALE
      CALL PLOTTTM(TDOSZ)
      PRINT*
      PRINT*
      PRINT*,"PLACE START OF PROTOTYPE"
      PRINT*,"AT SAMPLE 1 TO ",IDPSZ-IPRSZ,"   "
      READ*,IPRLO
      IF(IPRLO.LE.IDPSZ-IPRSZ) GO TO 105
      PRINT*,"MUST BE LESS THAN " ,IDPSZ -IPRSZ
      GO TO 103
C
C     CALL SUBROUTINE TO PLOT PROTOTYPE LOCATION
105   CALL PLOTPRO(IPRLO,IPRSZ,IDPSZ)
      CALL FINITT(1),TAG)
C
      LOC=IPRLO+IVIEW
110   PRINT*,"                                        ",
     1"START OF PROTOTYPE AT SAMPLE"
      PRINT*,"                                        ",
     1IPRLO
600   FORMAT(A1)
200   PRINT*,"                                        ",
     1"TYPE PROTOTYPE HOW MANY SAMPLES"
      PRINT*,"                                        ",
     1"MINUS TO MOVE LEFT  "
      PRINT*,"                                        ",
     1"PLUS TO MOVE RIGHT  "
      READ*,IMOV
      IF(IMOV.EQ.0) GO TO 300
      IPRLO=IPRLO+IMOV
C
C     CALL SUBROUTINE TO PLOT ECG
      CALL PLOTECG(IDATA,IDPSZ)
      GO TO 105
300   PRINT*,"STORE PROTOTYPE     "
      READ 600,I
      IF(I.EQ.1HY) GO TO 310
      IF(I.EQ.1HN) GO TO 320
      IF(I.EQ.1HS) GO TO 999
      PRINT*,"MUST BE YES OR NO"
      GO TO 300
```

```
310         DO 311 IK=1,64
            JK=IK+IPOLD-1
C
            FFTV(IK)=ADATA(JK)
311         IF(IK.GT.IPDSZ) FFTV(IK)=0.
C
            CALL FFT(FFTV,6,+1.)
C
            DO 316 I=1,6
            FVEC(NUMFVC,I)=REAL(FFTV(I))
316         FVEC(NUMFVC,I+6)=AIMAG(FFTV(I+1))
            IF(OUTPUT.EQ.1) GO TO 201
            NUMFVC=NUMFVC+1
C
            PRINT*,"PLOT VECTORS ? "
            READ 600,I
            IF(I.EQ.1HN) GO TO 320
C
CALL SUBROUTINE TO PLOT FFT VECTORS OR FREQUENCY SPECTRUM
            CALL PLTFVC(FVEC,NUMFVC,6,*,FREQEXP,FREQ)
C
            PRINT*,"CLEAR PROTOTYPE ARRAY? "
            READ 600,I
            IF(I.EQ.1HN) GO TO 319
            NUMFVC=1
            DO 317 I=1,20
            DO 317 J=1,64
317         FVEC(I,J)=0.
C
319         PRINT*,"REWIND DATA?  "
            READ 600,I
            IF(I.EQ.1HY) GO TO 92
            GO TO 320
201         DO 113 I=2,6
113         FREQUEN(I)=SQRT(FVEC(1,I)**2+FVEC(1,I+6)**2)
            DO 112 J=1,4
112         WRITE(2,666)(FVEC(1,I+(J-1)*4),I=1,4)
            WRITE(2,666)(FREQUEN(I),I=2,5)
            WRITE(2,666)(FREQUEN(I),I=5,5)
666         FORMAT(4F11.4)
C
C
320         PRINT*,"SHOW NEW SECTION OF PLOT?      "
            READ 600,I
            IF(I.EQ.1HY) GO TO 33
            IF(I.EQ.1HN) GO TO 114
            IF(I.EQ.1HS) GO TO 999
            PRINT*,"MUST BE YES OR NO!!!#@#$%^&***!!!!"
            GO TO 320
C
```

```
      IT=(IDPSZ**2)/8
      IVIEW=IVIEW+IDPSZ-IT
      DO 340 L=1,IT
      SDATA(L)=SDATA(L+IDPSZ-(IDPSZ**2)/8)
340   CONTINUE
      KT=(IDPSZ**2)/8+1
      IF(KD.EQ.10) GO TO 95
      GO TO 1000
900   PRINT*,"END OF FILE ",IFILE,".  GO TO NEXT FILE? "
      READ 600,I
      IF(I.EQ.1HN) GO TO 219
      IFILE=IFILE+1
      GO TO 85
999   STOP
      END
C**********************************************************************
C
C                PLOT EKG AND TIMING TRACES
C
C
      SUBROUTINE PLOTEKG(IDATA,IDPSZ)
      DIMENSION IDATA(1024)
      COMMON IEXP
100   IEXP=1024/IDPSZ
      CALL INITT(90)
           CALL MOVABS(0,IDATA(1))
           DO 120 K=2,IDPSZ,5
           CALL DRWABS((K-1)*IEXP,IDATA(K))
120        CONTINUE
      RETURN
      END
C**********************************************************************
C
C
C         PLOT PROTOTYPE LOCATION
C
C
      SUBROUTINE PLOTPRO(IPRLO,IPRSZ,IDPSZ)
      COMMON IEXP
      CALL MOVABS(IPRLO*IEXP,0)
      CALL DRWABS(IPRLO*IEXP,400)
      CALL MOVABS((IPRLO+IPRSZ)*IEXP,0)
      CALL DRWABS((IPRLO+IPRSZ)*IEXP,400)
      RETURN
      END
```

```
C*****************************************************************
C
C
C           PLOT TIME AXIS
C
      SUBROUTINE PLOTITM(IDPSZ)
      COMMON IEXP
      IF(IDPSZ.GT.100)GO TO 100
      CALL MOVABS(0,450)
      ITEN=IDPSZ/10
          DO 200 IK=1,ITEN
          CALL DRWABS(10*IK*IEXP,450)
          CALL DRWABS(10*IK*IEXP,400)
          CALL MOVABS(IK*10*IEXP,450)
200       CONTINUE
100   CONTINUE
      CALL MOVABS(0,500)
      IHUN=IDPSZ/100
          DO 300 IK=1,IHUN
          CALL DRWABS(100*IK*IEXP,500)
          CALL DRWABS(100*IK*IEXP,550)
          CALL MOVABS(100*IK*IEXP,500)
300       CONTINUE
      CALL FINITT(10,760)
      RETURN
      END
C*****************************************************************
C
C        PLOT EET VECTOR
C
      SUBROUTINE PLTEVC(EVEC,NUMEVC,S,M,FREQEXP,FREQ)
      DIMENSION S(15),M(15),AVEC(15),EVEC(20,15)
C
      IP=NUMEVC-1
      CALL INITT(30)
20    DO 140 J=1,IP
      IF(FREQ.NE.1) GO TO 40
      DO 30 I=1,7
      Z=SQRT(EVEC(J,I+1)**2+EVEC(J,I+8)**2)
      IPLVEC=Z*FREQEXP*S(I)+300+M(I)
      IF(I.EQ.1) CALL MOVABS(1,IPLVEC)
30    CALL DRWABS(120*I-120,IPLVEC)
      GO TO 140
40    CONTINUE
          DO 130 I=1,14
      IPLVEC=EVEC(J,I)*FREQEXP*S(I)+380+M(I)
      IF(I.EQ.1)CALL MOVABS(1,IPLVEC)
130   CALL DRWABS(60*I-50,IPLVEC)
140   CONTINUE
      CALL FINITT(0,780)
```

```
C*************************************************************
C     CHANGE VALUES THAT CONTROL THE PLOTING
C     OF THE FREQUENCY VECTOR.
C*************************************************************
300   PRINT*,"CHANGE     WEIGHT     MEAN     EXPAND      NONE
      PRINT*,"TYPE         W          M          E          N
      READ 500,I
      IF(I.EQ.1HE) GO TO 310
      IF(I.EQ.1HN) GO TO 320
C
      PRINT*,"WHICH COMPONENT 1 TO 16?  "
      READ*,ICOMP
      IF(I.EQ.1HW) GO TO 330
      PRINT*,"WEIGHT OF COMPONENT ",ICOMP," IS ",S(ICOMP)
      READ*,VAL
      S(ICOMP)=VAL
      GO TO 350
330   PRINT*,"MEAN OF COMPONENT ",ICOMP," IS "
     1,M(ICOMP),".  CHANGE TO?  "
      READ*,IVAL
      M(ICOMP)=IVAL
      GO TO 350
C       EXPAND ALL COMPONENTS
310   PRINT*,"EXPAND=",EXPOEXP,"   CHANGE TO ? "
      READ*,VAL
      EXPOEXP=VAL
      GO TO 350
C
320   PRINT*,"PLOT VECTOR AGAIN? "
      READ 500,I
      IF(I.EQ.1HY) GO TO 80
C
      PRINT*,"STORE AVERAGE OF VECTOR"
      READ 500,I
600   FORMAT(A1)
      IF(I.EQ.1HN)GO TO 520
      DO 505 I=1,16
C       FIND AVERAGE OF EACH COMPONENT
      SUM=0
      DO 510 J=1,IP
510   SUM=SUM+FVEC(J,I)
505   AVEC(I)=SUM/IP
      WRITE(2,501) (AVEC(II),II=1,8)
      WRITE(2,501) (AVEC(II),II=9,16)
501   FORMAT(8E10.4)
C
520   PRINT*,"RETURN TO FIRST FILE? "
      READ 500,I
      IF(I.EQ.1HY) REWIND 1
      RETURN
      END
```

```
      FFT

      SUBROUTINE FFT(X,M,XI) ! COMPLEX X(1),U,W,T
      N=2**M $ NV2=N/2
      NM1=N-1 $ J=1 $ PI=3.1415926535898 $ DO 7 I=1,NM1
      IF(I.GE.J) GO TO 5 $ T=X(J) $ X(J)=X(I) $ X(I)=T
5     K = NV2
6     IF(K.GE.J) GO TO 7 $ J=J-K $ K=K/2 $ GO TO 6
7     J=J+K $ DO 20 L=1,M $ LE=2**L $ LE1=LE/2 $ U=(1.,0.)
      W=CEXP(CMPLX(0.,-XI*PI/(LE1)) $ DO 20 J=1,LE1
      DO 10 I=J,N,LE
      IP=I+LE1 $ T=X(IP)*U $ X(IP)=X(I)-T
10    X(I) = X(I) + T
20    U=U*W $ IF(XI.GT.0.) RETURN $ DO 30 I=1,N
30    X(I)=X(I)/N $ RETURN $ END
```

```
C*************************************************************
C    PROGRAM TO LOCATE AND CLASSIFY
C    P WAVES USING FOURIER ANALYSIS
C*************************************************************
C     COMMANDS TO ATTACH NEEDED FILES
C     ATTACH,T,TEKPLOT,ID=APIT
C     LIBRARY,T
C     ATTACH,TAPE1,"DATA FILE"
C     ATTACH,TAPE2,"CONSTANTS AND MEANS FILE"
C*************************************************************
      PROGRAM FIND(INPUT=100,OUTPUT=100,TAPE1,TAPE2)
      DIMENSION IDATA(1024),DATA(10),ADATA(1024)
      DIMENSION SDATA(1024)
      DIMENSION GRPMEAN(3,2),FK(25),XK(25)
      COMMON ADATA
      DIMENSION HIST(50)
      DIMENSION PICKED(50)
C*************************************************************
C        INITIALIZE CONSTANTS
C*************************************************************
      REWIND 2
C
C  STARTING POINT OF SEARCH FOR MAX HIST VALUE
      IPNST=10
C
C  STOPING POINT OF SEARCH FOR MAX HIST VALUE
      IPNSTP=50
C   INDEX TO COUNT WHICH FILE IS DISPLAYED
      IFILE=1
C   NUMBER OF RECORDS READ IN THIS FILE
      IREC=0
      KI=1
C
C    NUMBER OF SAMPLE POINTS TO BE PLOTED IN EACH DISPLAY
      IDPSZ=1024
C
C      WIDTH OF EKG DATA WINDOW TO BE FFT AND TESTED
      IPRSZ=32
C
C      NUMBER OF SAMPLES TO BE OVERLAPED
      OVERLAP=16
C
C        NUMBER OF SUBSECTIONS IN EACH DISPLAY
      NUMSECT=(IDPSZ-IDPSZ/4)/(IPRSZ-OVERLAP)
```

```
      DO 1 I=1,50
C
C A HISTOGRAM OF PAST SELECTIONS OF
C THE P WAVE PROTOTYPE
      HIST(I)=0
C
C   A RECORD OF WHAT PAST SECTIONS WERE
C   SELECTED AS P WAVES
1     PICKED(I)=1
C**********************************************************
C   READ CONSTANTS FOR THE CANONICAL VARIABLE FUNCTION
C**********************************************************
      READ(2,600) YK
      READ(2,600) XK
600   FORMAT(6F10.5)
C**********************************************************
C      READ GROUP MEANS P WAVE, BASELINE, T WAVE
C**********************************************************
      DO 5 J=1,3
5     READ(2,633)(GRPMEAN(J,I),I=1,2)
633   FORMAT(2F10.5)
C**********************************************************
C        BACKSPACE TO BEGINNING OF FILE
C**********************************************************
92    IF(IREC.EQ.0) GO TO 96
      BACKSPACE 1
      IREC=IREC-1
      GO TO 92
C**********************************************************
C           FILL DATA ARRAY
C**********************************************************
95    IF(EOF(1)) 999,96
96    READ(1,603) DATA
603   FORMAT(10F6.0)
      KD=1
      IREC=IREC+1
100   SDATA(KI)=DATA(KD)
      IF(KI.EQ.IDPSZ) GO TO 104
      KI=KI+1
      KD=KD+1
      IF(KD.NE.17) GO TO 100
      GO TO 95
C**********************************************************
C   NORMALIZE MEAN
C**********************************************************
104   SUM=0
      IDPSZ=IDPSZ
            DO 106 JJ=1,IDPSZ
106           SUM=SUM+SDATA(JJ)
      XMEAN=SUM/IDPSZ
            DO 107 JJ=1,IDPSZ
107           ADATA(JJ)=SDATA(JJ)-XMEAN
```

```
C*************************************************************
C     NORMALIZE VARIANCE
C*************************************************************
      SSUM=0
            DO 105 JJ=1,IDPSZ
105         SSUM=SSUM+ADATA(JJ)**2
      SIG=SQRT(SSUM)/IDPSZ
            DO 109 JJ=1,IDPSZ
109         ADATA(JJ)=ADATA(JJ)/SIG
C*************************************************************
C          PREPARE DATA TO PLOT
C*************************************************************
      EXPAND=1
      SHIFT=200
            DO 111 JJ=1,IDPSZ
111         IDATA(JJ)=EXPAND*ADATA(JJ)+SHIFT
C*************************************************************
C   CALL SUBROUTINE TO PLOT EEG AND TEST SECTIONS
C*************************************************************
      CALL PLOT(IDATA,IDPSZ,IPRSZ,ADATA,OVERLAP,
     1NUMSECT,HIST,PICKED,IREC,YK,XK,SCRNCAN,IPHST,IPHSTM)
C
212   PRINT*,"SHOW NEW SECTION OF PLOT     "
      READ 600 ,I
600   FORMAT(A1)
      II=(IDPSZ*2)/8
      DO 340 L=1,II
      SDATA(L)=SDATA(L+IDPSZ-(IDPSZ*2)/8)
340   CONTINUE
      KI=(IDPSZ*2)/8+1
      IF(KD.EQ.16) GO TO 99
      GO TO 100
C
999   PRINT*,"END OF FILE ",IFILE,".  REWIND FILE ? "
      READ 600,I
      KI=1
      IF(I.EQ.IHY) GO TO 92
      PRINT*,"GO TO NEXT FILE ?  "
      IFILE=IFILE+1
      IREC=0
      DO 998 I=1,50
      HIST(I)=0
998   PICKED(I)=1
      READ 600,I
       IF(I.EQ.IHY) GO TO 98
      STOP
      END
C*************************************************************
C
C
```

```
      SUBROUTINE PLOT(IDATA,IPSZ,IPSZ,ADATA,DW,ZLAB
     1,NUMSECT,MIST,PICKED,IREC,YK,XK,GRPMEAN,IPMST,IPMSTP)
      DIMENSION GRPMEAN(3,2),YK(25),XK(25)
      DIMENSION V(64)
      DIMENSION FREQ(7)
      DIMENSION IDATA(1024),FVEC(16)
      COMPLEX V
       DIMENSION DIST(99)
      DIMENSION ADATA(1024)
      DIMENSION MIST(50),PICKED(50)
C
C    WIDTH OF TOLERANCE WINDOW
C    FOR PERIOD TEST
      WIDTH=2
      DO 1111 I=1,99
1111  DIST(I)=0
C
C          PLOT LOG
      CALL INITT(1200)
           CALL MOVABS(0,IDATA(1))
           DO 150 K=2,IPSZ,4
           CALL DRWABS(K-1,IDATA(K))
150        CONTINUE
C*****************************************************
C    CALCULATE CLOSEST GROUP MEAN
C    FOR EACH SECTION
C*****************************************************
           DO 325 LOCATE=1,NUMSECT
      MSTOP=LOCATE*(IPSZ-OVERLAP)+IPSZ/8
      MSTART=(LOCATE-1)*(IPSZ-OVERLAP)+IPSZ/8
C
C    PLACE SECTION INTO ARRAY TO
C    BE FFT
      DO 320 IX=1,64
      V(IX)=ADATA(IX+MSTART)
320   IF(IX.GT.IPSZ) V(IX)=0.
      CALL FFT(V,6,+1.)
C
C       TRANSFER LOW FREQUENCY REAL AND IMAGINARY COMPONENTS
C       INTO ARRAY FVEC
      DO 325 ITRANS=1,8
      FVEC(ITRANS)=REAL(V(ITRANS))
      FVEC(ITRANS+8)=AIMAG(V(ITRANS+1))
325   CONTINUE
```

```
C     FIND DISTANCE TO GROUP MEAN
C     USING CANONICAL VARIABLES
C
C*************************************************************
      DO 326 I=1,7
326   FREQ(I)=SQRT(FVEC(I+1)**2+FVEC(I+8)**2)
      SUM1=0
      SUM2=0
      DO 327 I=1,16
      SUM1=SUM1+FVEC(I)*XK(I)
327   SUM2=SUM2+FVEC(I)*YK(I)
      DO 328 I=1,7
      SUM1=SUM1+FREQ(I)*XK(I+17)
328   SUM2=SUM2+FREQ(I)*YK(I+17)
      Y=SUM2+YK(25)
      X=SUM1+XK(25)
C
C     FIND SMALLEST DISTANCE
      DISTP=SQRT((Y-GRPMEAN(1,1))**2+(X-GRPMEAN(1,2))**2)
      DIST3=SQRT((Y-GRPMEAN(2,1))**2+(X-GRPMEAN(2,2))**2)
      DIST4=SQRT((Y-GRPMEAN(3,1))**2+(X-GRPMEAN(3,2))**2)
      IF(DIST3.LT.DISTP) GO TO 329
      IF(DIST4.LT.DISTP)GO TO 330
      IF(DISTP.GT.6)GO TO 331
      DIST(LOCAT)=DISTP
      MIN=1
      GO TO 332
329   MIN=3
      GO TO 332
330   MIN=4
      GO TO 332
331   MIN=2
C*************************************************************
C     PLOT NEAREST PROTOTYPE FOR THIS SECTION
C*************************************************************
332   IF(MIN.NE.1) GO TO 333
      CALL MOVABS(MSTART,300)
      CALL DRWABS(MSTOP,350)
      CALL DRWABS(MSTOP,250)
      GO TO 334
333   CONTINUE
      IF(MIN.NE.2) GO TO 335
      CALL MOVABS(MSTART,300)
      CALL DRWABS(MSTOP,300)
      CALL DRWABS(MSTOP,200)
      GO TO 334
335   CONTINUE
      IF(MIN.NE.3) GO TO 336
      CALL MOVABS(MSTART,350)
      CALL DRWABS(MSTOP,350)
      CALL DRWABS(MSTOP,250)
      GO TO 334
```

```
370   CONTINUE
      IF(MIN.NE.4) GO TO 380
      CALL MOVABS(MSTART,500)
      CALL DRWABS(MSTOP,500)
      CALL DRWABS(MSTOP,200)
      GO TO 304
380   CONTINUE
      IF(MIN.NE.5) GO TO 390
      CALL MOVABS(MSTART,450)
      CALL DRWABS(MSTOP,450)
      CALL DRWABS(MSTOP,200)
      GO TO 304
390   CONTINUE
      CALL MOVABS(MSTART,400)
      CALL DRWABS(MSTOP,400)
      CALL DRWABS(MSTOP,200)
304   CONTINUE
      PICKED(1)=0
      IF(MIN.GT.1) GO TO 400
C*****************************************************************
C       CHECK FOR PROPER PERIOD
C*****************************************************************
C     PLACE FLAG IN ARRAY
      PICKED(1)=1
C     ADD PICKED TO HISTOGRAM
      DO 321 IFILL=1,64
321   HIST(IFILL)=PICKED(IFILL)+HIST(IFILL)
C   FIND LARGEST HISTOGRAM LOCATION
      MAX2=50
      HIST(MAX2)=0.
      DO 121 I=IPAST,IPAST2
121   IF(HIST(MAX2).LT.HIST(I))MAX2=I
C   RESET HISTOGRAM
      IF(HIST(MAX2).LT.30) GO TO 120
      DO 119 I=1,64
119   HIST(I)=0.
      HIST(MAX2)=2.
C   TEST PAST SELECTIONS
C   IF ANY IN THE WINDOW
C   CLASSIFY AS A P WAVE
120   LOCST2=MAX2-(WIDTH/2)
      LOCST2=MAX2+(WIDTH/2)
      DO 122 I=LOCST2,LOCST2
122   IF(PICKED(I).EQ.1)GO TO 341
      GO TO 400
C*****************************************************************
C       PLOT P-WAVE INDICATOR
C*****************************************************************
341   MARK=MSTART+10
      CALL MOVABS(MARK,700)
      CALL DRWABS(MARK,700)
C
```

```
C     OUTER ARRAY PICKED TO THE RIGHT
400   DO 450 IX=1,64
400   PICKED(81-IX)=PICKED(81-IX)
350         CONTINUE
      CALL PINIT(0.,80)
C
      PRINT*,DIST
      IF(IRSD.GT.30) RETURN
C
      PRINT*,"NUMBER OF SUBSECTIONS IN ONE R CYCLE"
      READ*,IRCYC
      IRHST=IRCYC/2
      IRHSTP=FLOAT(IRCYC)*1.1+1.
      RETURN
      END
C*****************************************************************
C
C           FFT
C
      SUBROUTINE FFT(X,N,YT) ! COMPLEX X(1),U,W,T
      N2=2*N ! NV2=N/2
      NM1=N-1 ! J=1 ! PI=3.14159265358979 ! DO 7 I=1,NM1
      IF(I.GE.J) GO TO 6 ! T=X(J) ! X(J)=X(I) ! X(I) =T
      K = NV2
6     IF(K.GE.J) GO TO 7 ! J=J-K ! K=K/2 ! GO TO 6
7     J=J+K ! DO 20 L=1,M ! LE=2**L ! LE1=LE/2 ! U=(1.,0.)
      W=CMPLX(COS(PI/LE1),-SIN(PI/LE1)) ! DO 20 J=1,LE1
      DO 10 I=J,N,LE
      IP=I+LE1 ! T=X(IP)*U ! X(IP)=X(I)-T
10    X(I) = X(I) + T
20    U=U*W ! IF(XI.GT.0.) RETURN ! DO 30 I=1,N
30    X(I)=X(I)/N ! RETURN ! END
```

Calcomp Conversion Subroutine

These subroutines produce a Calcomp plot of the Tektronixs display. They are added to either program and replace the Plot-10 subroutines. The display is enclosed in a six by nine inch rectangle.

```
SUBROUTINE INITT(ICPS)
CALL PLOTS(ICPS)
CALL PLOT(0.0,-3.,-3)
CALL PLOT(11.1,0.0,2)
CALL PLOT(11.1,8.5,2)
CALL PLOT(0.0,8.5,2)
CALL PLOT(0.0,0.0,2)
CALL PLOT(1.3,1.3,-3)
CALL PLOT(8.4,0.0,2)
CALL PLOT(8.4,7.2,2)
CALL PLOT(0.0,7.2,2)
CALL PLOT(0.0,0.0,2)
CALL PLOT(.3,.7,-3)
RETURN
END
SUBROUTINE ETWIT(IX,IY)
CALL PLOTF(IDUM)
RETURN
END
SUBROUTINE MOVABS(IX,IY)
XINCH=FLOAT(IX)/1024.
YINCH=FLOAT(IY)/1024.
IF(ABS(XINCH).GT.8.5) XINCH=8.5
IF(ABS(YINCH).GT.11.0) YINCH=11.0
CALL PLOT(XINCH,YINCH,3)
RETURN
END
SUBROUTINE DRWABS(IX,IY)
XINCH=FLOAT(IX)/1024.
YINCH=FLOAT(IY)/1024.
IF(XINCH.GT.8.5) XINCH=8.5
IF(YINCH.GT.11.0)YINCH=11.0
CALL PLOT(XINCH,YINCH,2)
RETURN
END
```

Vita

Captain Charles A. Flick was born 3 September 1946 in Dayton, Ohio. He graduated from high school in Englewood, Ohio, in 1964, and received the degree of Associate in Science from Sinclair Community College in December, 1967. He enlisted in the U. S. Air Force in December, 1969, and received the degree of Bachelor of Science in Electrical Engineering from Auburn University in August, 1972. He was commissioned a Second Lieutenant in the U. S. Air Force through the Airman Education and Commissioning Program in November, 1972. He served as Electronic Engineer with AFLC Detachment 41 at Vandenberg AFB, California. He entered the resident graduate electrical engineering program at the Air Force Institute of Technology in June, 1976.

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19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Algorithms to locate and identify the P wave in single lead electrocardiograms (ECG's) are developed and evaluated on eighteen 12 second electrocardiogram recordings. The program does not assume that the P wave has any specific time relationship to the occurence of the QRS complex. The program searches the entire ECG to locate the P wave

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in any part of the ECG. The program divides the ECG into sections and classifies the sections as P waves or some other wave. The first test selects the sections that have a frequency domain pattern that is similar to a training set P wave. The sections that pass this test are checked for a periodic relationship with past selected sections. If a section was selected at a time assumed to be one P wave period before the present one, the present one will be classified as a P wave. Of the 209 P waves in the ECG records, 123 or 58.85% were located correctly. There were 83 false classifications of sections which were not P waves.